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JOURNAL OF THE
SOCIETY OF GLASS TECHNOLOGY

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JOURNAL

OF THE

SOCIETY OF GLASS TECHNOLOGY

COMPRISING

PROCEEDINGS AND REPORTS, TRANSACTIONS

AND

ABSTRACTS OF PAPERS FROM OTHER JOURNALS

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The Society of Glass Technology.

The Society of Glass Technology was inaugurated at a meeting in the University of Sheffield, on Thursday, November 9th, 1916.

Its object was defined as the general advancement of the various branches of Glass Technology by the association of persons interested in glass and glassware; the reading and discussion of papers; the publication of scientific information on glass technology; the formation of a library and museum.

All persons or associations of persons interested in glass, whether from the point of view of the manufacturer, the distributor, the scientist, the user or collector, are eligible for membership.

Membership is of three classes: Collective Membership, open to Firms, Associations, and Committees; Ordinary Members, and Student Members, the annual subscription in each class being £3 3*s*., £1 10*s*., and 2*s*. 6*d*. respectively. Copies of the Constitution and Rules may be had on application to the Secretary, The University, Sheffield. The total number of members whose election has been confirmed exceeds 650.

Meetings of the Society are arranged monthly, except during the summer. One half of the meetings take place at Sheffield, the headquarters of the Society, the other meetings being held in different centres of the glass industry, as the Council decides. In this way local interest is stimulated.

The Society publishes a Quarterly Journal, containing the papers read to the Society and the discussions on the papers, together with abstracts of other papers of interest to members published in British and foreign journals. Each collective member may receive two copies and each ordinary member one copy.

Scientific communications on glass technology are invited for publication in the Journal.

A library of technical literature has been formed, and a list of the books available for reference or for loan may be obtained from the Secretary.

The Society of Glass Technology.

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ERRATA.

Vol. IV. (Trans., 1920).

Page.	Line.	
211	16	*for* " gas-fired " *read* " coal-fired."
212	29	*for* " Calendar " *read* " Callendar."
216	Table	*for signs* " + " and " – " *read* " =."
218	2	*for* " 1500 " *read* " 1300."

Vol. V. (Trans., 1921).

130	Table III.	*transpose* " 4700 " and " 5200."
168	23	*for* " Table II " *read* " Table III."
180	5*	*for* " 100 " *read* " 1400."
181	13*	*insert* " (1)."
181	2*	*insert* " (1)."
290	18	*for* " c.m." *read* " kilo.-mol."
353	13	*for* " increased " *read* " decreased."

Vol. V. (Abs., 1921).

58	6*	*for* " B_2O_2 " *read* " B_2O_3."

Vol. VI. (Trans., 1922).

22	9*	*for* " SiO_2 " *read* " CrO_3."
25	10*	*for* " CrO_3 " *read* " SiO_2."

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* From Bottom.

W. F. J. WOOD, C.B.E., B.Sc., F.I.C.,
First President of the Society
(*November* 1916 *to April* 1919).

[*Frontispiece.*

PROCEEDINGS

PROCEEDINGS

OF THE

SOCIETY OF GLASS TECHNOLOGY

PROCEEDINGS OF THE FORTY-NINTH MEETING.

Held in the Metallurgical Department, Applied Science Department, the University, St. George's Square, Sheffield, on Wednesday, January 18th, 1922, at 2.30 p.m., the President, Dr. Morris W. Travers, F.R.S., in the Chair.

The President intimated that a party of members of the American Ceramic Society would visit this country about the end of August or the beginning of September of this year. Members of the Society of Glass Technology who visited America in 1920 were treated with the greatest courtesy and hospitality, and he was sure that an equally warm welcome would be extended to their American friends on their arrival in this country. A Committee had been formed to deal with the reception arrangements. Meantime, any suggestions concerning visits to works, or other matters likely to be of interest to their American friends, would be welcomed.

The proceedings then took the form of a general discussion on The Durability of Glass, several papers being presented in illustration of various aspects of the problem.

The first paper was entitled "An Examination and Extension of Zulkowski's Theory of the Relation between the Composition and Durability of Glasses," by W. L. Baillie, A.I.C. In the absence of Mr. Baillie an Abstract of his paper was given by Prof. W. E. S. Turner, D.Sc. The President and Mr. J. R. Clarke, M.Sc., took part in the discussion that followed, Prof. Turner replying.

A paper entitled "The Effects of Magnesia on the Durability of Glass," by Miss C. M. M. Muirhead, B.Sc., and Prof. W. E. S. Turner, D.Sc., was given by the latter, and illustrated by lantern slides. There contributed to the discussion that followed, the President, Messrs. F. G. Clark, and J. R. Clarke, M.Sc. Prof. Turner replied.

Prof. W. E. S. Turner, D.Sc., also presented a paper entitled "A Critical Note on the Methods of Determining the Durability of Glass." In the discussion that followed there took part, the President, Messrs. J. R. Clarke, A. Bunce, W. J. Rees, E. A. Hailwood, and F. W. Adams. Prof. Turner replied.

The fourth paper on the agenda, "The Action of Various Reagents on the Surface of Chemical Glassware," by Prof. W. E. S. Turner, D.Sc., and T. E. Wilson, B.Sc., was presented but not read, owing to lack of time.

Hearty votes of thanks were accorded to the authors of the papers presented.

The President intimated that the next meeting would be held in Manchester, on February 15th, at which part of the time would be devoted to considering questions submitted by members.

The following were elected Ordinary Members :—

1. Howard Cornell Herger	*Analytical Chemist*, Messrs. Pierce Glass Co., 663, Main Street, Buffalo, N.Y., U.S.A.
2. William Tibbits Honiss, B.S.	*Mechanical Engineer*, Messrs. Hartford-Fairmont Co., Hartford, Conn., U.S.A.

PROCEEDINGS OF THE FIFTIETH MEETING.

Held in the Chemistry Lecture Theatre, The College of Technology, Manchester, on Wednesday, February 15th, 1922, at 2.30 p.m., the President, Dr. Morris W. Travers, F.R.S., in the Chair.

In directing the attention of members to the fact that the Society was meeting for the fiftieth time, the President said that from small beginnings at the end of 1916, the Society had steadily increased its activities and membership. The number of members was now some 650, drawn from various parts of the world, about one hundred being American. He hoped that when the Society celebrated its one hundredth meeting it would be able to report a continued increase in its usefulness and prosperity.

A cordial vote of thanks was accorded to the authorities of the College of Technology, Manchester, for their courtesy in providing accommodation for the Society's meetings.

A paper entitled " The Relative Advantages and Disadvantages of Limestone, Burnt Lime and Slaked Lime as Constituents of Common Glass Batches containing Soda-Ash and Salt-Cake, Part II," by F. W. Hodkin, B.Sc., A.I.C., and Prof. W. E. S. Turner, D.Sc., was presented by the latter, and illustrated by lantern slides. A discussion followed in which there took part the President, Messrs. W. J. Rees, G. Simpson, A. S. Giles, and F. G. Clark. Mr. Hodkin and Prof. Turner replied.

A paper entitled, " The Density of Soda-Magnesia Glasses and the Calculation of Density in General," by S. English, M.Sc., A.I.C., and Prof. W. E. S. Turner, D.Sc., was presented but not read.

Votes of thanks were accorded to the authors of the papers presented to the meeting.

The remainder of the meeting was devoted to a continuation of a discussion, begun at the Leeds meeting on November 16th, 1921, on " The Melting of Glass." The following questions were considered :—

1. What is the objection to using a large quantity of cullet? What are the troubles it is likely to cause? If there are any, then what is the safe maximum proportion of cullet to batch?

2. (*a*) What is the procedure to adopt in order to ascertain the homogeneity of glass?
   (*b*) Is it better to fill into the furnace batch and cullet separately, or batch and cullet mixed?
   (*c*) Is it better to fill into the furnace, batch and cullet, by the use of a crane-filling shovel through the charging door, and distribute them over as great an area as possible, or through the doghouse filled by the overhead batch hopper?

3. For a window glass averaging 73 per cent. silica, and 14 per cent. lime, 13 per cent. soda, are there different physical properties, viscosities, difficulties in handworking, due to the nature of the batch, either soda-ash or salt-cake? Should window glass made with soda-ash be inferior to window glass made with salt-cake, or less workable in glass gathering? It would seem apparent that the use of soda-ash as constituent of the batch is more efficient as to the life of the tank blocks and also as to the clouding of the window glass cylinders reheated in the furnace flame containing sulphur from salt-cake, and consequently worthy of commendation.

4. How long prior to working should a melt be maintained at "plaining" temperature once it is already plain?

These questions were discussed by the President, Prof. W. E. S. Turner, Messrs. W. R. Barker, J. H. Bickerton, W. Butterworth, F. G. Clark, J. Connolly, A. S. Giles, P. Haller, F. W. Hodkin, G. Simpson, V. H. Stott, and Duncan Webb, jun.

The following were elected Ordinary Members:—

1. Paul Delalande, Chevalier de la Légion d'Honneur.	*Manager*, Messrs. Établissements Etienne Henry, 10, Rue Lavoisier, Paris, France.
2. Georges Despret.	*Manager*, Messrs. Société des Glaces et Verres Spéciaux du Nord de la France, 59, Rue de Châteaudun, Paris.
3. John Alfred Mitchell-Withers.	14, Oakholme Road, Sheffield.

PROCEEDINGS OF THE FIFTY-FIRST MEETING.

Held in St. Thomas's Hall, Stourbridge, on Wednesday, March 15th, 1922, at 2.45 p.m., the President, Dr. Morris W. Travers, F.R.S., in the Chair.

The President having intimated the death of two members of the Society, Dr. J. F. Bottomley and Major A. H. Heisey, it was resolved that these be recorded with regret in the minutes of the meetings of the Society.

It was announced that the Annual Dinner would be held this year in Sheffield, on Wednesday evening, April 26th, in the Royal Victoria Station Hotel. Members were invited to apply to the Secretary for tickets as soon as possible.

A paper entitled "Some Notes on the Production of Colourless Glass in Tank Furnaces," by A. Cousen, B.Sc., A.R.C.S., and Prof. W. E. S. Turner, D.Sc., was presented by the latter.

A discussion followed to which there contributed the President, Messrs. E. A. Coad-Pryor, W. P. Johnson, and W. J. Rees. Mr. Cousen and Prof. Turner replied.

Mr. W. J. Rees, B.Sc.Tech., F.I.C., followed with a paper entitled "A Review of the Preliminary Specifications for Refractory Materials used in the Glass Industry."

This paper provoked an interesting discussion, in which there took part the President, Col. C. W. Thomas, Prof. W. E. S. Turner, Mr. E. A. Coad-Pryor, and Major G. V. Evers. Mr. Rees replied.

The President having to leave the meeting before the discussion closed, the chair was taken, in his absence, by Col. C. W. Thomas.

Votes of thanks were accorded to the authors of the papers presented to the meeting.

The following members were elected :—

(*a*) *Collective Members.*

Messrs. Peter Gilston & Co.	Manufacturers of Flint and Green Glass Bottles, Hunslet Carr, Hunslet, nr. Leeds.

(*b*) *Ordinary Members.*

1. William Edward Laycock.	*Works Manager*, Messrs. Evans & Co., 51, Paragon Road, Hackney, London, E. 9.

2. Robert Malcolm.	*Glass Manufacturer*, 2300, Warren Avenue, Chicago, Ill., U.S.A.
3. Joseph Keith Matthews, B.A.	*Fuel Technologist*, Messrs. Pearson & Knowles Coal & Iron Co., Ltd., Warrington.
4. Charles Henry Modes.	*Superintendent of Furnace Operation and Glass Making*, Messrs. Illinois Glass Co., Alton, Ill., U.S.A.
5. Naomichi Harada.	*Manager*, Messrs. Nippon Glass Co., Hodogaya, Yokohama, Japan.
6. Walter W. Oakley.	*Engineer*, Messrs. Corning Glass Works, Corning, N.Y., U.S.A.
7. John Thomas Wood.	*Tank Manager*, Messrs. Portland Glass Co., Ltd., Irvine, Ayrshire.
8. Frederick Arthur Harrison, A.M.I.Mech.E.	*Engineer*, Messrs. British Glass Industries, Ltd., Canning Town, London, E. 16.

During the forenoon, by the courtesy of the respective directors, members had an opportunity of visiting the works of

(*a*) Messrs. King Brothers (Stourbridge), Ltd.
(*b*) Messrs. E. J. and J. Pearson, Ltd.

An opportunity for social intercourse was provided before the meeting, when members lunched together at the Talbot Hotel, Stourbridge.

VISIT TO THE CHARLTON WORKS OF MESSRS. UNITED GLASS BOTTLE MANUFACTURERS, LTD.

A large party of members (about 80) visited the works of the United Glass Bottle Manufacturers at Charlton, London, S.E. 7, on December 14th, 1921, and spent some two hours making a thorough inspection of the plant.

The works, situated near the river Thames, occupy some 35 acres of land, and are designed to operate automatically as far as possible, and to utilise labour-saving devices and up-to-date machines. The raw materials are conveyed (by a bucket-conveyor) from the railway trucks into concrete bins capable of holding about 600 tons of sand. The sand is passed through a rotary hot air drier before being filled to the sand bin. The bins are arranged in a row astride of a track along which an electrically driven car and weighbridge rides, collecting the requisite amount of raw materials from each bin through hoppers at the bottom of the bin operated by levers which can be controlled from the operator in the car. The cullet is crushed, elevated, and conveyed on a belt conveyor to the cullet bin, passing over a magnetic separator.

After collecting the batch, the car discharges its contents into a rotary mixer, from which the batch is elevated to a car running some 40 feet above the ground level adapted to discharge into a row of hoppers situated over the filling end of the furnaces. These hoppers each contain about 40 tons of batch, rather more than one day's output, for the furnace which the hopper feeds. At the time of the visit three furnaces were in operation, two making amber glass and one high quality flint glass. Two Owens machines are operated from each furnace, but owing to the fire which had broken out on the works a few weeks previously, two machines were temporarily out of action. A fourth furnace was nearing completion.

The machines normally produce all types of bottles; at the time of the visit 1 oz., 4 oz., and 16 oz. Bovril bottles were being made, and 8 oz. medical bottles. About 30 tons of glass per day were being drawn from each furnace, the machines making from 20–60 bottles per minute (depending, of course, on the size of the bottle). The lehrs, which were of the muffle type, were situated below the level of the furnace floor, the bottles being conveyed down shoots to the front of the lehrs. Each machine employs two lehrs, making in all therefore, 12 lehrs, and, in addition, four others are nearing completion.

The works (lehrs, furnaces, boiler plants, etc.), were operated on oil fuel (Shell Mex.), and oil firing was found to be giving very satisfactory results. Air blown burners were in use at pressures of about 25 lb.

The factory is equipped with a mould shop for supplying the machines with the necessary equipment and power stations for the production of the pressure and vacuum needed for the machines.

Those of the party who did not leave early were entertained with light refreshments.

VISIT TO THE WORKS OF MESSRS. E. J. AND J. PEARSON, LTD., STOURBRIDGE.

Wednesday, March 15th, 1922.

The firm dates back to 1860, when it was commenced under the above title at the Delph and Tintam Abbey Firebrick Works near Stourbridge, and between 1861 and 1920 the output has increased nearly seven-fold.

The fireclay mines are situated at Delph, Crown, Iron Jack, Birch Tree, Ravensitch, and Homer Hill, whilst the firebrick works are located at Delph, Tintam Abbey, Crown, Homer Hill, and Brettell Lane.

The Tintam Abbey works are now used solely for the manufacture of glasshouse pots. Delph works have been greatly enlarged, the latest addition in 1920 being the building of a new fifteen-chamber continuous kiln. The Crown works were built in 1877, and have since been much enlarged. The equipment includes a twenty-eight-chamber continuous kiln built in 1912. Homer Hill works, together with the mines and estate, belonging previously to Samuel Evers & Sons, were purchased in 1916 to cope with the heavy pressure of war work.

Brettell Lane works, belonging previously to the late Mr. H. T. Hickman, were purchased at the same time as the Homer Hill works.

From these different pits the Company is able to offer clays of varying characteristics, some of them best suited for one purpose, and some for another. Thus, the various products of the Company are supplied for glass works, and for gas, steel, iron, cement, pottery, engineering, spelter, and many other industries. The number and variety of different sizes of firebrick kept in stock for so many different purposes are surprising. It is said that the Company attempt to keep as many as 4,000 different sizes and patterns always in stock, quite apart from the large number of "specials" continually being made for one purpose or another. The Company's manufactures, when in full swing, entail a consumption of considerably more than 1,000 tons of clay per week, and it is a matter of pride to the Directors that they have kept on their works on full time until this month, March, 1922.

Careful records are kept of every batch of clay used for different orders, whether for tank blocks, pots, or any other purpose, and regulars tests are made as to the refractory standard, porosity, shrinkage, and composition.

The Company fully recognises the importance of improving the life of tank blocks. Co-operation with glass manufacturers is welcomed and is already bearing good fruit. The Company is prepared to work to definite undertakings as regards analysis, refractory standard, and porosity. Samples were shown to the visitors having a porosity of under 20 per cent. in a mixture containing 70 per cent. of grog.

It is recognised that owing to the changed conditions of glass works practice some alteration to the old standards for tank blocks is necessary. The following analysis is put forward as perhaps the most suitable for present day requirements for flux line purposes.

	per cent.
SiO_2	60·1
TiO_2	1·6
Al_2O_3	34·8
Fe_2O_3	1·5
CaO	0·3
MgO	0·5
Alkali	1·3
	100·1

Porosity . . . . . . 22·9 per cent.
Refractory standard. Cone 31—32.

At the Homer Hill works a considerable development is about to be undertaken at once, namely, the building of extensive souring pits capable of holding many hundreds of tons of tank block clay.

Engineering Department.

The Company undertakes, not only the supply of materials, but also the actual setting of retorts whenever required, and have secured very excellent results in many instances.

In this Department also, the setting of boilers is undertaken and special attention is directed to the patent asbestos-cushioned seating blocks and flue covers. Out of the many hundreds of boilers set on this principle, the firm has never been called on to replace a single piece of asbestos between the seating blocks and the boiler. The economy due to a perfect seal between the side and bottom flue must obviously be considerable, and the life of the boiler is greatly increased owing to the fact that no abrasion takes place on the line of contact between the boiler and the seating blocks.

OBITUARY NOTICES.

We record with very great regret the death of two members of outstanding reputation in the silica and glass industries :

James Francis Bottomley, Ph.D.

Dr. Bottomley was one of the early members of the Society, having been elected in June, 1917. He is best known for his work in the development of the fused silica ware industries in connection with which his researches began twenty years ago. It was from these researches that the electrically fused silica glass, best known under the trade term of " vitreosil," was developed, and is nowadays being used for many different types of vessel, large and small, in which freedom from corrosion by acids is its main feature. In several ways this silica ware, through Dr. Bottomley's efforts, is becoming a rival to glass, one of the newest developments being its use for manufacturing incandescent globes and chimneys for gas lighting purposes.

Dr. Bottomley was Managing Director of the Thermal Syndicate, Ltd., at Wallsend-on-Tyne, and was the Director also of a number of other technical companies.

Major Augustus H. Heisey.

Major A. H. Heisey, of the firm of Messrs. A. H. Heisey & Co., Newark, Ohio, was a prominent figure in the glass industry of the United States and was by no means unknown to members of the industry in this country. The writer recalls with much pleasure a visit paid, in company with another member of the Council, to Newark in 1919. Major Heisey was then actively engaged in business, despite his seventy-seven years, and he looked as physically fit as many men ten to fifteen years his junior.

The following information is taken from the *Newark Advocate* of February 14th, 1922 :

Major Heisey at the time of his death was seventy-nine years of age. His military service covered practically the whole of the Civil War, in which he rose from the rank of Private to Major, was wounded at the battle of Gettysburg, 1863, and was cited in orders for his gallantry in action. Except for short periods, practically his life had been spent in the glass industry, being engaged in succession with the King Glass Co. of Pittsburgh, the Ripley Glass Co. of Pittsburgh, and the George Duncan & Sons Glass Co., Pittsburgh, up to 1889. His own glass business now so well-known throughout the States was founded in 1895. In addition to his activities as a glass manufacturer he was for thirty years President of the Pittsburgh Clay Pot Co., President of the American Protective Tariff League, and served also as Director, and in some cases as founder, of a number of other undertakings. He gave constantly and generously to philanthropic undertakings.

MORRIS W. TRAVERS, D.Sc., F.I.C., F.Inst.P., F.R.S.,

Third President of the Society

(*April* 1921 *to April* 1922).

[*Frontispiece.*

PROCEEDINGS OF THE FIFTY-SECOND MEETING, BEING THE FIFTH ANNUAL GENERAL MEETING.

HELD in the Applied Science Department, the University, St. George's Square, Sheffield, on Wednesday, April 26th, 1922, at 2.30 p.m., the PRESIDENT in the Chair.

The Fifth Annual Report of the Council (together with the Balance Sheet) for the year 1921 having been circulated, was taken as read, approved, and adopted.

The Report ran as follows :—

FIFTH ANNUAL REPORT OF THE COUNCIL.

THE membership of the Society on December 31st, 1920, stood at 620. During the year 1921, 63 new members were elected, of whom 5 were Collective and 58 Ordinary Members. In addition, the first Honorary Member was elected.

The statement of membership may be summarised in the following tables which enable a survey to be made of the geographical distribution of membership.

A. *Total Members elected up to the end of* 1921.

Honorary	1
Collective	149
Ordinary	569
Student	24
	743

B. *Members on the Roll, December* 31*st*, 1921.

Location.	Honorary.	Collective.	Ordinary.	Student.	Totals
British Isles	1	126	363	4	494
Argentina	—	—	1	—	1
Australia	—	2	3	—	5
Belgium	—	—	1	—	1
Canada	—	—	5	—	5
China	—	—	4	—	4
France	—	4	6	—	10
Holland	—	1	1	—	2
India	—	1	11	—	12
Japan	—	2	14	—	16
South Africa	—	1	2	—	3
Spain	—	—	1	—	1
Sweden	—	—	7	—	7
U.S.A.	—	5	97	—	102
	1	142	516	4	663

It will be noted that the foreign membership has more than kept pace with the additional membership in the British Isles.

Of the new members, some 11 are resident in the United States, and it is anticipated that further increases will take place of members resident there, especially in view of the efforts of Mr. Wm. M. Clark, the American Treasurer, and of other members of the Society in making known our activities, and in giving publicity to the JOURNAL.

In these times, when efficiency counts for so much, the Council believes that every firm in the British Isles interested in the glass industry should be a member of the Society, and so acquire all the latest technical information available.

The Council has to regret the death of the following member during the year :—

C. M. Brooke.

The following members have resigned :—

(*a*) *Collective.*

British and Foreign Bottle Co.
British Chemical Ware Manufacturers' Association, Ltd.
British Glass Industries, Ltd. (Leeds Branch).
Campbell Bros.
J. Crosfield & Sons.
General Electric Co., Ltd.
Harvey Free, Ltd.
Indian Munitions Board.
Lambeth Glass Works, Ltd.
Scientific Glass Co.
Thompson Glass Co.
P. T. Turner & Co., Ltd.
Thos. Webb & Sons, Ltd.
Welsbach Light Co., Ltd.
Webb's Crystal Glass Co., Ltd. (Tutbury Branch).

(*b*) *Ordinary.*

J. Callie.
C. F. Claudon.
Col. O. L. Eugster.
R. F. Hind.
Dr. R. S. Hutton.
F. A. Kirkpatrick.
Miss C. M. M. Muirhead.
R. McInnes.
C. K. McLeod.
H. M. Read.
G. W. Reynolds.
W. H. Trewartha-James.
T. E. Wood.
A. R. Young.

Eight members have been removed through non-payment of subscription.

At the Annual General Meeting in 1921 a number of changes were made in the Society's Constitution and Rules and new copies of the Constitution and Rules have been printed and circulated to all members. One important change was the institution of Honorary Membership, and Prof. P. G. H. Boswell, who had given such excellent service to the Society during its early years, was elected the first Honorary Member.

The Society also felt that it might with advantage reduce the number of Vice-Presidents from 12 to 6, the reduction being spread over a period of three years.

Bearing in mind the numerous anxieties which all members of the industry have borne during 1921, the attendance at meetings must be considered as very good. Two meetings of exceptional interest were the discussion on the use of Oil Fuel in the Glass Industry, and the general discussion on the Melting of Glass and allied problems. The discussion on the latter subject introduced a new feature, which was very much appreciated, into the work of the Society, and will probably be continued from time to time.

During the year, the Society on the occasion of its meetings has had the opportunity of visiting several splendidly equipped works. The Council desires to acknowledge the kindness of the firms in question and to thank them for the privilege so afforded.

The fifth volume of the JOURNAL contained 44 pages of Proceedings, 32 original papers contributed to the Society occupying 363 pages, and 383 Abstracts and Reviews occupying 220 pages. These figures represent an increase in the number of Abstracts and Reviews over Vol. IV. The number of papers in the Transactions remains the same, but the total pages occupied are somewhat fewer.

The number of volumes in the Society's Library at the end of 1921 was 190, representing an increase of 15. A catalogue was compiled during the year and is in the press.

Following the Annual General Meeting in April, the Third Annual Dinner was held at the Hotel Cecil, London, when 97 members and guests were present.

The Council expressed its readiness to co-operate with the National Physical Laboratory in connection with a Conference on Scientific Glassware held in London. At this Conference it was proposed to form a Standing Committee on the Standardisation of Scientific Glassware, and the Council nominated the President of the Society, Dr. M. W. Travers, F.R.S., to represent it on this Committee.

In August, 1921, the Society learned with much pleasure that the American Ceramic Society had accepted the invitation to visit this country in the early autumn of 1922. This visit is eagerly anticipated as confirming and establishing the good relationship between the two Societies.

Despite the difficult financial position of the industry, the Balance Sheet of the Society is to be regarded as highly satisfactory, and as some indication of the way in which it meets the technical needs of the industry. The total income for the year amounted to £1,787 19*s.* 6*d.* Of this the cost of printing the JOURNAL and abstractors' remuneration amounted to more than £1,230. The sales of various numbers of the JOURNAL have also been considerable, amounting to £261 17*s.* 3*d.* On the year's working, there results a balance of £84 19*s.* 4*d.*, which, with the balance in hand, makes a total balance of £122 10*s.* 6*d.*

SOCIETY OF GLASS TECHNOLOGY.

DINNER ACCOUNT, 1921.

EXPENDITURE.

				£	s.	d.
To Deficit, 1920 Account				5	8	7
,, Hotel for Dinner	51	9	0			
,, ,, for Printing	2	2	0			
				53	11	0
,, Other Printing				1	8	0
,, Postages					16	8
,, Gratuities				2	10	0
,, Balance, being Excess of Income over Expenditure						1
				£63	14	4

INCOME.

				£	s.	d.
By Tickets sold	64	2	6			
Less Returned	3	10	0	60	12	6
,, Donation from Dr. M. W. Travers				3	1	10
				£63	14	4

SOCIETY OF GLASS TECHNOLOGY.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING DECEMBER 31ST, 1921.

EXPENDITURE.	£	s.	d.	£	s.	d.
To Abstractors' Remuneration				44	9	6
,, Advertising				3	15	0
,, Bank Charges				2	14	6
,, Binding Books and Periodicals				21	14	6
,, Binding and Cases for Journal				20	15	0
,, Books and Periodicals				7	7	6
,, Carriage					7	5
,, Expenses of Meetings				4	19	0
,, Library List				19	0	0
,, List of Members				25	5	0
,, Office Expenses				8	2	3
,, Postages, etc.				44	6	7
,, Printing, etc., of Journal No. 17	332	6	10			
No. 18	279	0	0			
No. 19	275	10	1			
No. 20	211	15	0			
				1098	11	11
,, Printing Notices and Stationery, etc.				81	12	1
,, Printing Preliminary Matter and Enlarged Index, Vol. I.				16	1	3
,, Reprints, Authors', Journal No. 17	26	10	6			
No. 18	17	7	9			
No. 19	17	1	8			
No. 20	14	2	6			
				75	2	5
,, Salaries				220	2	8
,, Travelling Expenses				8	13	7
,, Balance, being surplus of Income over Expenditure for the year 1921				84	19	4
				£1787	19	6

INCOME.	£	s.	d.	£	s.	d.
By subscriptions :						
(*a*) Collective				396	18	0
(*b*) Ordinary				568	10	0
(*c*) Student					10	0
(*d*) American *				119	3	6
(*e*) Odd Amounts				10	10	11
(*f*) Paid 1920 for 1921				18	3	0
(*g*) In Arrears				4	16	0
				1118	11	5
,, Bank Interest				19	1	0
,, Binding Cases sold to Members ...	6	15	1			
Ditto—Non-members		7	3			
				7	2	4
,, Journals sold to Members ...	83	15	7			
Ditto—Non-members	178	1	8			
				261	17	3
,, Commission on Advertisements in Journal						
No. 17	103	10	0			
No. 18	94	10	0			
No. 19	90	0	0			
No. 20	93	7	6			
				381	7	6
				£1787	19	6

* Less expenditure *re* Purchase of American Periodicals, etc., and for advertising.

SOCIETY OF GLASS TECHNOLOGY.

BALANCE SHEET AS ON DECEMBER 31ST, 1921.

LIABILITIES.	£	s.	d.	£	s.	d.
Advertising	...		...	1	5	0
Abstractors' Remuneration	...		...	34	9	6
Binding Books and Periodicals ...	...		...	21	14	6
Binding and Cases for Journal ...	...		...	20	15	0
Library List	...		...	19	0	0
List of Members	...		...	25	5	0
Printing, etc., of Journal No. 19 ...	275	10	1			
No. 20 ...	211	15	0			
				487	5	1
Reprints, Authors', Journal No. 19 ...	17	1	8			
No. 20 ...	14	2	6			
				31	4	2
Subscriptions in Advance	...		...	9	6	0
Subscriptions in Excess and Repayable	...		...	1	11	8
Balance from 1920 Balance Sheet ...	37	11	2			
Add Surplus of Income over Expenditure for 1921	84	19	4			
				122	10	6
				£774	6	5

ASSETS.	£	s.	d.	£	s.	d.
Cash in Hand, Sheffield	6	15	4			
,, Bank, Sheffield	458	0	1			
,, Bank, U.S.A.	16	13	6			
				481	8	11
Commission on Advertisements :						
Journal, No. 18	94	10	0			
No. 19	90	0	0			
No. 20	93	7	6			
				277	17	6
Subscriptions in Arrears				15	0	0
Journals, etc., in Stock :						
				£774	6	5

Journals, etc., in Stock :

No.		No.	
No. 1	—	No. 9	52
,, 2	62	,, 10	46
,, 3	46	,, 11	73
,, 4	33	,, 12	42
,, 5	—	,, 13	187
,, 6	—	,, 14	196
,, 7	9	,, 15	208
,, 8	21	,, 16	204
,, 17	409	Including 200 of each in sheets for binding in volume.	
,, 18	416		
,, 19	413		

Vol.	Bound Volumes		Binding Cases	
Vol. I.	Bound Volumes	92.	Binding Cases	61
,, II.	,, ,,	35.	,, ,,	30
,, III.	,, ,,	148.	,, ,,	25
,, IV.	,, ,,	185.	,, ,,	29

We have audited the above Balance Sheet for the year ending December 31st, 1921, with the Books, Accounts, and Vouchers relating thereto, and certify it as being in accordance therewith.

F. P. WAINWRIGHT,
DENNIS WOOD, F.S.A.A.

March 31*st*, 1922.

The meeting then proceeded to the election of officers for the year 1922–23.

The following lists contain the names (1) of officers whose term of office expired, and (2) of Members who were elected in accordance with the Rules of the Society to fill the vacancies.

President.

(1)	(2)
M. W. Travers, D.Sc., F.Inst.P., F.I.C., F.R.S.	Prof. W. E. S. Turner, O.B.E., D.Sc., M.Sc., F.Inst.P.

Vice-Presidents.

G. E. Alexander, O.B.E.	W. W. Warren, A.M.I.C.E., A.M.I.E.E.
J. E. Foxon.	C. J. Peddle, M.B.E., D.Sc., F.I.C., F.Inst.P.
Congreve Jackson.	W. Butler.*
Col. C. W. Thomas.	

Ordinary Members of Council.

F. J. Boam.	H. H. Asquith.
S. English, M.Sc., A.I.C.	W. Butterworth, Jnr., M.A.
J. S. Shaw.	J. H. Davidson, M.Sc., F.I.C.
W. W. Warren, A.M.I.C.E., A.M.I.E.E.	F. W. Hodkin, B.Sc., A.I.C.
Duncan Webb, Jnr.	V. H. Stott, M.Sc.

Treasurers.

F. G. Clark (General).	J. Connolly (General).
Wm. M. Clark, Ph.B. (American).	Wm. M. Clark, Ph.B. (American).

Secretary.

W. E. S. Turner, O.B.E., D.Sc., M.Sc., F.Inst.P.	F. Graves Clark.

Assistant Secretary.

C. J. Peddle, M.B.E., D.Sc., F.I.C., F.Inst.P.	S. English, M.Sc., A.I.C.

Auditors.

F. P. Wainwright.	Edward Meigh, M.B.E., M.Sc.
Dennis Wood, F.S.A.A.	Dennis Wood, F.S.A.A.

Dr. M. W. Travers gave a hearty welcome to his successor as President, Prof. W. E. S. Turner, and then vacated the Chair.

Prof. Turner expressed his sincere thanks, both to Dr. Travers and to the audience, for the great welcome they had given him in assuming the office of President.

Hearty votes of thanks were accorded to the retiring officers of the Society for their services during the past year.

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* To fill vacancy caused by election of Mr. J. Connolly as General Treasurer.

Dr. M. W. Travers, the retiring President, replied.

On the motion of Mr. F. Graves Clark, seconded by Dr. M. W. Travers, it was Resolved—

> That a grant of Fifty Pounds (£50) be made to the Department of Glass Technology, The University, Sheffield, to promote research.

Prof. W. E. S. Turner, O.B.E., D.Sc., then delivered the Presidential Address, his subject being, "The British Glass Industry, Its Development and Outlook."

Mr. J. Connolly said he had been asked to propose a vote of thanks to their President for his address. Before doing so, he must first of all congratulate the Society in having secured for its President such an industrious man as Professor Turner. He had stated in his historical survey that at a certain period there were noblemen of high rank interested in the glass trade. He thought they had got a nobleman to-day as President. Prof. Turner evidently realised, in the latter part of his address, that a great cause and a great inspiration were not sufficient: they must certainly be accompanied by a great victory. The latter part of his address, he thought, made a call on them, and he was sure they all felt they had had plenty of food for reflection. They hoped that both health and strength would be given to the President to continue right through the year.

Mr. W. Butler said he had very great pleasure in seconding the vote of thanks given to Prof. Turner for his wonderful speech that afternoon, and he would like to impress on those who had to deal with its publication that no word should be left out. It contained hope and encouragement which all manufacturers needed, and he would like to see a full verbatim report distributed widely at as early a date as possible.

The Very Reverend William Foxley Norris, D.D., Dean of York, addressed the meeting on "The Medieval Glass of York Minster."

A discussion followed in which there took part the President, Dr. M. W. Travers, W. Butler, and T. Robertson.

An opportunity for social intercourse was afforded after the meeting, when tea was provided.

The following were elected members :—

(*a*) *Collective Members.*

Messrs. Yorkshire Amalgamated Products, Ltd., 27, Waterdale, Doncaster.
The Ohio State University, Columbus, Ohio, U.S.A.

(*b*) *Ordinary Members.*

Ibri Lucas Sills, B.Sc.	*Chemist*, Messrs. Consumers Glass Company, P.O. Box 40, Montreal, Canada.
Wilbur Robert Smith.	Messrs. Illinois Glass Co., Bridgeton, N.J., U.S.A.
Archibald Hall.	*Glass House Manager*, Messrs. British Glass Industries, Ltd., Canning Town, London, E. 16.
William John Moody-Smith.	*Engineer*, Messrs. British Glass Industries, Ltd., Canning Town, London, E. 16.
Professor C. W. Waggoner, B.S., A.M., Ph.D.	*Professor of Physics*, West Virginia University, Morgantown, W.Va., U.S.A., and Consulting Engineer to Glass Manufacturing Companies.

FOURTH ANNUAL DINNER.

The Fourth Annual Dinner of the Society was held in the Royal Victoria Station Hotel (Great Central Railway), Sheffield, on Wednesday, April 26th, 1922, at 7.15 p.m.

The President, Prof. W. E. S. Turner, O.B.E., D.Sc., occupied the Chair, the company including the Right Honourable, the Lord Mayor of Sheffield (Alderman Charles Simpson), Sir Albert J. Hobson, LL.D. (Pro-Chancellor, The University, Sheffield, and late President Association of British Chambers of Commerce), Sir W. H. Hadow, D. Mus. (Vice-Chancellor, The University, Sheffield), the Very Reverend W. Foxley Norris, D.D. (Dean of York), Mr. A. L. Hetherington (Department of Scientific and Industrial Research) and Dr. M. W. Travers, F.R.S. (Past President of the Society). An apology for absence was received from Col. C. W. Thomas (President of the Ceramic Society.

The following were the toasts :—

I. "The King."

Proposed by the President.

II. "The Glass Industry."

Sir Albert J. Hobson, LL.D., in proposing "The Glass Industry," said that what perhaps occurred to him most of all at the present time was that the whole of the industries of the country were in an unsatisfactory and disorganised state, and he ventured to assume for the moment that the glass industry was not very much more prosperous than the general run of the industries. If that were so, he thought that we needed to look at the whole subject and try to get some conception as to why things were as they were, and what was the best way to alter them.

The products of industry throughout the war were in very short supply, and we were mortgaging the future with reckless disregard for the consequences. One of the results of this was that we got into a period of greatly inflated prices which enabled enormous profits to be made by manufacturers and very large wages to be paid to the workers. Unfortunately, the manufacturers' profits were very largely in the nature of fairy gold; they had turned to brown leaves since; for the manufacturers had been subjected to war taxation, and after having been persuaded to inflate all their commodities to the top price, taxation was levied on them on the top of these prices. The excess profits turned out to be levied, not on realised profit at all, but on anticipated profits, which were not being realised in the balance sheets that were being presented for the post-war periods. The wages that were paid to the workers were of a somewhat more solid character, although he was afraid that the greater proportion of these wages were extravagantly spent, and therefore the one opportunity in a hundred years of the working classes getting well in front of their engagements had not been used as one would like to have seen it used. His experience was that it was always an advantage to have around one workmen who were prepared to save money. It was a curious thing, but the habit of saving grew on one, and the more prosperous a workman became the steadier he was because of that prosperity. We had now come to the point at which we were falling away from these times of inflated values, and there were various ideas about which seemed to him to be very unsound and were vitally prejudicing the recovery of industry. He wanted to refer to one or two of them, and if they did not happen to apply particularly to the glass industry they at all events applied to the particular industries with which he was rather more familiar. The first fault that he had to find with the state of affairs at the present time was that there was a very general assumption throughout the country that it is not necessary to make things as sound and as well-finished as they were before the war. He had had to remonstrate with his own men about the bad finish of their productions, and he had been told with an air of indolent surprise: "Well, you don't expect them finished the same as they were before the war, do you?"—as if it were an extremely unreasonable thing to expect.

One had to reflect, however, that Great Britain, owing to the insularity of its geographical position, was dependent on other countries for its raw material or food, which had to be exchanged for our high-class manufactured goods. We, in our proud little island, could not live by taking in one another's washing; we had to live by our export trade; and the man at the other end of the world who took our goods in exchange for his raw materials, whether it happened to be copper, tin, spelter, rubber, jute, rice, or what-not else—was as keen on seeing that we kept up our quality as we expected him to keep up his. Many of the raw materials that we were buying from him were now down to their pre-war price, or nearly so, and the quality was as good as ever it was before the war. If, then, we were to measure wages according to the commodities of exchange, the man at the other side of the world was entitled to receive from us more and better work than before the war. One was afraid, however, that at the moment we were not giving him a fair exchange, although one would hesitate to say that the best way of giving him a fair exchange was necessarily to get back to lower wages. The most important thing was efficiency of production, and the getting back to the best standard of work. If we could only persuade our workmen to give us of their best we could afford to pay them high wages. The time had now arrived when everyone connected with industry in this country—workmen, designers, foremen, engineers, or whoever they might be—should realise that nothing but the very best efforts could be expected to restore that state of industrial prosperity of which we had been so proud in the days before the war.

"We here, at Sheffield University," continued Sir Albert, "were drawn into making provision for practical training in connection with the glass industry partly by the enthusiasm of Dr. Turner—and it is extraordinary what the enthusiasm of one man will do for an industry—and partly by patriotic reasons also; for we felt that the glass industry needed more science to restore it to its old prosperity, which, even before the war, was somewhat less marked than one desired to see in connection with any of the old industries of the country. And since the war we have continued to take a keen interest at the University in the glass industry, in the hope that we should be able to promote efficiency in that industry. So far as you may be able to tell us that the work that has been done at Sheffield University has helped towards efficiency, you will be able to tell us the one thing that we would like to hear you say. I trust that we shall be able to go on helping towards greater efficiency in the glass industry, and I trust that everyone concerned in it will feel the necessity of giving the best value possible.

"Let me say one thing more. There is no more absolutely ruinous doctrine being preached in this country at the present time than the doctrine that restricted output helps to create additional work in industry. My experience is that this is totally untrue. It is a great fallacy; for if, by making three articles instead of two, these three articles could be sold a third cheaper, there would be a much greater call for them. If an article could be sold at half the price it would command four to five times the volume of trade. And there is no actual limit that could ever be put on the volume of trade that could be done if we could only produce goods cheap enough. There is an unlimited demand throughout the world for desirable things—good glass amongst them, for good glass is a very desirable thing. If you could only persuade everyone who is smitten by this extraordinary doctrine of restricted output that wealth consists, not in a scarcity of commodities, but in an abundance of them, you will have done something to promote very greatly the prosperity of your industry.

"I trust that as we get farther away from the state of artificial inflation which was created by the war, we shall be able gradually to induce all those connected, not merely with the glass industry in particular, but with all our other great industries, that wealth consists in the abundance of goods and the cheapness of their production consistent with good quality, for that is the surest way back to commercial prosperity. I hope that the glass industry will return speedily to a state of prosperity, along with the other industries of the country. And may I say here, in the presence of so many who are intimately associated with the glass trade, that the sooner it returns to a state of prosperity the better will it be for the community as a whole; for every industry that finds peace, prosperity, and contentment acts as a stimulus to every other industry, and is an encouragement to them to tread the same path? I have, therefore, the greatest pleasure in wishing 'Prosperity to the Glass Industry.'"

Col. S. C. HALSE, in responding for the "Glass Industry," said: Prof. Turner told us something this afternoon about old bones and new blood. I don't know what he is, but I am the new blood. I feel that I have been in the industry such a short time that it is impossible for me to answer the question that was raised, inferentially at least, by Sir Albert Hobson as to whether the glass-worker is turning out goods of the same finish as he was before the war. Certainly from my own small experience I think it is most likely that he is not, because I am always having grumbles from my workers that I expect too much from them. I suppose I may have concluded that my workers have got into loose habits during the war, and that they are not anxious to get out of them, and I assume, therefore, that what Sir Albert Hobson has suggested is correct. Another of Sir Albert's points was rather more cheerful in tone, and that was, that there is an unlimited demand for anything that is good. Now in my particular section of the glass trade we only make common bottles and jars, so that I assume what Sir Albert means is that if only the beer and the whisky are good there will assuredly be a demand for the bottles.

As to the help that the glass industry obtains from the Society of Glass Technology, again speaking from my own limited outlook, I think it is enormous. I have always found that the staff at Sheffield have been anxious to give us every assistance in their power. They even agreed to one of their staff coming to our works for some weeks to give us some help, and he was of most valuable assistance in that particular phase of the work that he came down to help us with. I feel we are not honoured above other people in a matter of this sort, and there is no doubt at all that the help that the Sheffield staff have given to us they are also giving simultaneously to the trade as a whole, which is benefiting thereby all the time. May I express the sincere hope that by the time the next annual dinner of the Society comes round the prospects of the glass trade will be considerably improved?

III. "The Society of Glass Technology."

Dr. WM. FOXLEY NORRIS, in proposing "The Society of Glass Technology," said that he appreciated highly the great privilege of having been permitted to address the Society that afternoon and of being entrusted with that toast at the dinner. He gathered that the Society was of very recent formation and that it had grown from a membership in 1917 of 263 to a membership this year of more than 660; also that the Society had now members in nine foreign countries, besides the whole of the British Possessions. This was evidence that the Society was quickly and worthily taking its place. He assumed that it was the endeavour of the Society to give an accession of brain power to the whole of the glass industry, and after all, any industry must ultimately depend for its success on brains—on expert knowledge and research. He supposed that one thing that we had rather suffered from in this country in the past had been the absence of time and money for research. The Society of Glass Technology was one of many institutions which were now seeking to rectify that. He hoped that the movement would succeed in doing all that was expected of it.

Concluding, Dr. Norris said that if the Society, at any time in the future, by representation or otherwise, might care to honour York with a visit, he would like to hold out a very cordial invitation to them, and he could promise them that every facility would be accorded them of seeing the wonderful glass at York Minster of which he had had something to say to them that afternoon.

Prof. W. E. S. TURNER, responding for the Society of Glass Technology, said that he had great sympathy for the glass manufacturers in the bad times through which they were at present passing. He believed that many who were absent would, under normal conditions, have made a point of being present, in order to show how much they respected the Society. The serious part of his speech must be brief, but there were three things at any rate that he must say. In the first place, he must reply to the kind invitation of the Dean of York to pay a visit to York Minster. On behalf of the members he would like to say that they would be delighted to accept at some favourable opportunity the invitation so kindly and charmingly given. Secondly, he would also like to say that this year they were looking forward with much eagerness to welcoming a body of men with like interests to theirs from America. Already they had had one meeting with their American friends, across the Atlantic in 1920. This year they were hoping to have a return visit, and he wanted to say to the Lord Mayor of Sheffield that they would expect a royal welcome from the civic authorities in the beginning of September, when that visit was expected to be made.

The third point he would like to mention was that the year through which the Society had just passed had been exceptionally successful. He did not propose to review it, except to say that despite the difficulties, Dr. Travers in his presidential capacity had had a most successful year. The attendances at the meetings had been good. Finally, he would like to say that he felt the Society had that day taken a step in the right direction. This was the first year in which the Society had become possessed of a real working balance—something over £100—and the Council of the Society had taken the opportunity of voting from that balance a grant of £50 with the object of stimulating research in the Department of Glass Technology at the University of Sheffield. Sir Albert Hobson, who had given them such an able speech that evening, was not only the late president of the Associated Chambers of Commerce, but also the Pro-Chancellor of this University, and he was sure that Sir Albert would take the announcement that had just been made as some indication that there was a recognition on the part of the Society of Glass Technology that the University was rendering valuable help to the glass industry. He looked forward to another prosperous and happy year for the Society, and he sincerely hoped that within a few months trade conditions might take on a much better appearance.

IV. " The Guests."

Dr. M. W. Travers, in proposing " Our Guests," said that the Society appreciated it as an honour to have with them that evening so many influential gentlemen, headed by the Lord Mayor of Sheffield. Many of these gentlemen were known to all present either personally or by fame. The opportunity of addressing the Society's guests provided one with an opportunity of speaking of the connection of the Society of Glass Technology with the outer public. That connection should be a very wide one. If one looked round the room one could not help seeing glass on all sides—glass beautiful and glass otherwise. Unfortunately, the general public knew very little about glass. This was evident from the things which one often saw in the glass and china shop windows. Even the glass which one sometimes saw in our church and cathedral windows, which was supposed to be the most beautiful expression of the art of glass painting, did not always edify or please one. He thought it was high time that a serious effort was made to bring the science and technology of glass-making definitely before the notice of the general public. He thought something ought to be done to cause the public to realise, as they had not yet realised, that the highest expression of art in glass-making was being revealed in the modern productions of the British Isles. Now their guests were representatives of the great British public whom the glass manufacturers served, and who ought to be in a position to know what this great industry was doing. If they did not know it was the fault of the glass manufacturers. He thought this was a lesson which they ought to take to heart. If a larger number of people could be brought to understand more clearly what British glass is and what it yet might be, he felt certain that something tangible would be done to improve the present state of trade and to advance the British glass industry in general. They had much pleasure in seeing with them that evening as their guests representatives of the British public from so many different angles, and they all hoped that such points of contact would tend to improve the knowledge of the general public in regard to glass and its production.

The Lord Mayor of Sheffield responded, remarking that the Society's guests were greatly indebted for the opportunity of being present and for the kind way in which their health had been drunk. They were all interested in the success of any of the home industries, and, as Sir Albert Hobson had said, if a period of prosperity could come to the glass industry it would have a marked influence on all the other industries of the country, because all industries were mutually interdependent and inter-related. With regard to the prospective visit of the American Ceramic Society, he could assure them that, if this visit should take place, it would be the endeavour of the civic authorities of Sheffield to give them a real Yorkshire welcome and a "right good time."

During the evening, musical selections were rendered, the artists being Miss G. Bagshaw and Mr. A. Renwick Sheen. Mr. W. F. Pearson was accompanist.

The following members and guests were present :—

Alderman, G.
Alexander, J. H.
Asquith, H. H.
Asquith, M.
Batley, W. (Press).
Boam, F. J.
Burdin, N.
Clark, F. Graves.

Clark, H. Noël.
Clarke, J. R.
Clarke, Mrs. J. R.
Connolly, Joseph.
Connolly, Miss E.
Connolly, Miss G.
Davidson, J. H.
Dimbleby, Miss V.
Duncan, G. S.
Firth, Miss E. M.
Fitzgerald, E.
Gibbons, W. M.
Hadow, Sir W. H.
Halse, Col. S. C.
Hetherington, A. L.
Hobson, Sir Albert J.
Inglis, C. G.
Jackson, A. H.
Lamplough, F. E.
Mitchell-Withers, J. A.
Norris, Dr. W. Foxley (Dean of York).
Norton, L. E.
Parkinson, C.
Parton, W. H. (Press).
Pearson, W. F.
Ripper, Prof. W.
Robertson, E. D. J.
Sheen, A. R.
Simpson, C. (Lord Mayor of Sheffield).
Smart, G. W.
Snowdon, W. C.
Sutcliffe, T. C.
Teisen, Th.
Tinkler, W.
Townsend, H. (Press).
Travers, Dr. M. W.
Turner, Prof. W. E. S.
Turner, Mrs. W. E. S.

Total 46.

PROCEEDINGS OF THE FIFTY-THIRD MEETING.

HELD in the Chemistry Lecture Theatre, University College, Gower Street, London, W.C. 1., on Wednesday, May 17th, 1922, at 3.0 p.m., the President, Prof. W. E. S. TURNER, D.Sc., in the Chair.

The PRESIDENT directed the attention of members to the work and objects of the Glass Container Association of U.S.A., to which reference was made in his Presidential Address.

Mr. T. C. Sutcliffe, a member of the Society, had considerable information with regard to the Glass Container Association. This information he would be pleased to put at the service of members.

The PRESIDENT also directed the attention of members to the fact that there were now available—

(*a*) A Roll of Members for the autograph signatures of members, and

(*b*) A Suggestion Book.

It was hoped that a complete roll of members would be obtained in the course of time, and at each meeting he hoped that members who had not previously done so would sign the roll.

In regard to the suggestion book, it was provided for definite use and members would assist the Society by making use of it.

On the motion of Mr. W. B. CLARKE, seconded by Mr. W. BUTTERWORTH, a vote of thanks was accorded to the Directors of Messrs. J. Powell & Sons (Whitefriars), Ltd., for their kindness in permitting members to visit their works during the forenoon.

A vote of thanks was also accorded to the authorities of University College, London, for their courtesy in providing accommodation for the meetings of the Society.

A paper by JOHN CURRIE, M.A., entitled, " Columnar Structure in Sandstone Blocks," was read by Mr. S. English, M.Sc., in the absence of the author. Photographs showing the structure were exhibited. The President and Dr. M. W. Travers contributed to the discussion that followed.

A paper illustrated by lantern slides and specimens of glassware was given by F. W. ADAMS, M.Sc., entitled, " Some Practical Notes on the Manufacture of White Glass in a Tank Furnace."

A discussion followed in which there took part the President, Dr. W. Rosenhain, and Messrs. E. A. Coad-Pryor, R. L. Frink, J. H. Davidson, Donald Turner, W. B. Clarke, G. Simpson, and Edward Meigh. Mr. Adams replied.

Votes of thanks were accorded to the authors of the paper, presented to the meeting.

In order to give members an opportunity of having tea together in the College Refectory, the third paper on the Agenda was held over for the next meeting, namely, "The Composition of Lime suitable for Various Purposes in Glass Making," by Miss V. Dimbleby, B.Sc., and Prof. W. E. S. Turner, D.Sc.

The following were elected members :—

(*a*) *Collective Members.*

Messrs. Société des Verreries Schneider, Epinay, Seine, France.

(*b*) *Ordinary Members.*

E. Wilson Heisey.	*Vice-President*, Messrs. A. H. Heisey & Co., Newark, Ohio, U.S.A.
Birendra Kumar Shaw.	Messrs. Calcutta Glass and Silicate Works, Ltd., and Proprietor of the Electrical Glass-house, 3, Beadon Street, Calcutta, India.
Arthur Renwick Sheen.	13. St. Gabriel's Road, Cricklewood, London, N.W. 2.

VISIT TO THE GLASS WORKS OF JAMES POWELL & SONS (WHITEFRIARS), LTD., TUDOR STREET, LONDON, E.C.

Prior to its meeting on Wednesday, May 17th, 1922, the Society had the privilege of paying a visit to the famous old works at Whitefriars owned by Messrs. James Powell & Sons.

The glasshouse is the oldest in London, and is built on the site of the old Carmelite monastery founded in the reign of Edward the First.

Although little is known for certain as to exact dates, some of the older part of the structure, in the caves below the furnaces, for example, is evidently of very great antiquity. The earliest printed record of Whitefriars Glassworks is an account that appeared in *The Tatler* for August, 1710, where it is stated that—

> " At the Flint Glass-house in White-Fryars near the Temple, are made and sold by Wholesale or Retale, all sorts of Decanthers, Drinking Glasses, Crewits, &c., or Glasses made to any Pattern, of the best Flint; as also all Sorts of common Drinking Glasses, and other Things made in ordinary Flint Glass, at reasonable Rates."

The works came into the possession of Mr. James Powell in 1834, and since that time have remained in the family until the formation of the present company in 1919.

The manufactures at present carried on are stained glass windows and mosaics, constructed on the lines followed by mediæval artists, high quality flint glass domestic and table ware, lead and soda glass tube for chemical and scientific purposes, and lens fronted thermometer tube.

The party from the Society was a large one, and it was found necessary to divide it into two portions. Each party was conducted through the departments of the works and the various methods of manufacture were explained and illustrated. The mosaic artists were shown at work, forming mosaic tablets, inscriptions, and designs, by arranging together small blocks of various coloured glasses that are made in the furnaces on the premises. They were taken into the studios, where artists were working on cartoons and designs to be executed in glass, and from there into the glass-painters and cutters' departments, where the operations of cutting the various shapes of coloured glasses to fit the designs that had been prepared in the studio were witnessed. Then followed a visit to the painters, who were seen painting the delicate tracery and details of the figures in pigment composed of finely ground coloured glass, which is afterwards burnt on in the kilns. The demonstrations of this branch of work were concluded by a visit to the glazing shops, where the previously prepared fragments of coloured and painted glasses were fitted together in the lead framing which forms the complete window.

Some fine examples of memorial windows just completed for Sandhurst College were on view.

The visitors were next taken into the showrooms, where patterns of cut and blown Whitefriars flint glass, in the form of table decoration, etc., were seen. After this the party was taken into the glass-house and there shown the operation of tube-making, wine glass manufacture and the fabrication of heavy hand-made glassware. Finally a visit to the caves below the furnaces was made, and here the teasers were seen at work tending the furnaces. While below the furnaces, an opportunity was given for an examination of some of the ancient masonry already referred to.

This concluded the visit, and the members expressed themselves very pleased with what they had seen.

PROCEEDINGS OF THE FIFTY-FOURTH MEETING.

Held in the Applied Science Department, the University, St. George's Square, Sheffield, on Wednesday, June 21st, 1922, at 2.45 p.m., the President, Prof. W. E. S. Turner, D.Sc., in the Chair.

The President announced that a cable had been received from Dr. E. W. Tillotson, to the effect that the American Ceramic Society had decided to postpone the visit to England which had been planned to take place this year. The decision was received with great regret and the following Resolutions were passed unanimously :—

> *A.*—That the Council be authorised to renew its invitation to the American Ceramic Society to visit this country during 1923.
>
> *B.*—That the co-operation of the Ceramic Society be invited so that the renewed invitation may, if possible, be sent jointly by the Ceramic Society and the Society of Glass Technology.

A vote of thanks was accorded to the authorities of Sheffield University for their courtesy in providing accommodation so readily for the meetings of the Society.

The President intimated that they hoped to hold the next meeting, in October, in York, so that members might have an opportunity of accepting the kind invitation given to them by the Dean of York at the April meeting to inspect the stained glass windows of York Minster.

A paper, entitled, "On the Devitrification caused upon the Surface of Sheet Glass by Heat," by Y. Amenomiya was read by Prof. W. E. S. Turner in the absence of the author.

A paper, entitled, "Note on the Effect of Alumina in Retarding the Devitrification of Glass," by K. Kamita and Prof. W. E. S. Turner, D.Sc., was read by Mr. Kamita after the subject had been introduced by Prof. Turner. The paper was illustrated by lantern slides. A discussion followed to which there contributed Dr. R. D. Bain, Messrs H. W. Howes, W. J. Rees, and P. J. Haller. Prof. Turner replied.

The third paper presented to the meeting was entitled : "The Swelling of Sand on Absorption of Moisture and its Effect on

Batch Mixing," by L. E. Norton and Prof. W. E. S. Turner, D.Sc. This paper was read by Mr. Norton, and illustrated by lantern slides.

In the discussion that followed there took part, Messrs. W. J. Rees, R. S. Smith, J. H. Davidson, Dr. R. D. Bain, H. W. Howes, F. J. Boam, G. Simpson, W. Butterworth, jun., W. C. Snowdon, and P. J. Haller. Prof. Turner and Mr. Norton replied.

A paper, entitled, "The Mixing of Batch," by Miss V. Dimbleby, B.Sc., A. W. Dickenson, and Prof. W. E. S. Turner, D.Sc., was given by the latter and illustrated by lantern slides.

Messrs. J. H. Davidson, M. Parkin, G. Simpson, and H. W. Howes contributed to the discussion that followed. Prof. Turner replied.

In order that members might have the opportunity of having tea together, the reading of the last paper on the agenda was postponed, namely, "The Composition of Lime suitable for Various Purposes in Glass Making," by Miss V. Dimbleby, B.Sc., and Prof. W. E. S Turner, D.Sc.

During the forenoon a party of members visited the new premises and laboratories of the Department of Glass Technology, The University, at Darnall Road, Sheffield.

The following were elected members :—

(*a*) *Collective Members.*

Messrs. Société Anonyme des Cristalleries du Val St. Lambert, Belgium.

(*b*) *Ordinary Members.*

Roger Francis Bacon.	c/o Messrs. Wm. Cory & Son, Ltd., 52, Mark Lane, London, E.C. 3.
John William Farmer.	c/o Messrs. Rockware Glass Syndicate, Ltd., Greenford, Middlesex.
R. D. Mailey, B.S.	*Factory Manager and Chief Engineer*, c/o Messrs. Cooper Hewitt Electrical Co., Hoboken, New Jersey, U.S.A.
Alexander Scott Russell, B.A., F.C.S.	*Research Chemist*, c/o Messrs. United Glass Bottle Manufacturers (Charlton), Ltd., Charlton, London, S.E. 7.
James Plummer Weaver, B.Sc.	*Factory Chemist*, c/o Messrs. Libbey-Owens Sheet Glass Co., Charleston, W.Va., U.S.A.

PROCEEDINGS OF THE FIFTY-FIFTH MEETING.

Held in the Tempest Anderson Hall of the Yorkshire Philosophical Society, York, on Wednesday, October 18th, 1922, at 3.0 p.m., the President, Prof. W. E. S. Turner, D.Sc., in the Chair.

The President reported that Mr. Harry J. Powell was prevented by illness from being present and giving his paper entitled "Modern Developments in the Making of Stained and Painted Glass." In spite of his illness, Mr. Powell sent his paper to the Dean of York so as to be available at the meeting, and an abstract of it was read by Mr. F. E. Lamplough, M.A.

The Secretary was instructed to send Mr. Powell a message of sympathy from the Society, and its best wishes for his speedy recovery.

The death of Mr. Alfred Wilson, of Doxey, near Stafford, was recorded with regret.

A vote of thanks was accorded to the Very Reverend William Foxley Norris, D.D., Dean of York, for the courtesy he had extended to the members of the Society who inspected the windows of the Minster under his guidance during the forenoon.

A vote of thanks was also accorded to the Yorkshire Philosophical Society for providing accommodation for the Society's meetings, and to Dr. W. E. Collinge, Keeper of the Yorkshire Museum, for his courtesy during the forenoon in showing members the Roman remains, Roman glass, and other objects of interest under his charge.

The President directed the attention of members to the "Roll of Members" and to the "Suggestion Book." Both books were passed round during the meeting.

A paper, illustrated by specimens and lantern slides, was read by Mr. John A. Knowles, entitled "Processes and Methods of the Mediæval Glass Painters."

A discussion followed to which there contributed the President, Messrs. F. W. Branson, Donald Robertson, T. Robertson, and F. E. Lamplough. Mr. Knowles replied.

Votes of thanks were accorded to the authors of the papers presented to the meeting.

The following were elected members :—

(*a*) *Collective Member.*

Messrs. Kavalier Glassworks, Sazava, Czechoslovakia.

(*b*) *Ordinary Members.*

1. Rama Charan, B.Sc.	Student, Department of Glass Technology, the University, Sheffield.
2. Walter Cox.	*President*, Messrs. Pennsylvania Wire Glass Co., 914, Pennsylvania Building, Philadelphia, Pa., U.S.A.
3. Kurd Endell, Dr.Phil.	*Professor of Ceramic Engineering*, Technische Hochschule, Charlottenburg, Berlin.
4. Harold Victor Ernest Melville Renn.	*Superintendent of Graduating and Testing Departments*, Messrs. Duroglass, Ltd., Walthamstow, London, E. 17.
5. Georges Roque.	*Engineer*, c/o Messrs. Verreries Souchon, Neuvesel, Givors, Rhône, France.
6. Victor Sauvageon.	c/o Messrs. Société du Verre Electrique, 7, Rue de Pétrograd, Paris.

PROCEEDINGS OF THE FIFTY-SIXTH MEETING.

HELD in the Applied Science Department, the University, Sheffield, on Wednesday, November 22nd, 1922, at 3.15 p.m., the President, Prof. W. E. S. TURNER, D.Sc., in the Chair.

A cordial vote of thanks was accorded to Messrs. Parkgate Iron and Steel Co., Ltd., Rotherham, for their courtesy in permitting members to visit their works during the forenoon.

The presentation of two "Frank Wood" medals followed. An account of the ceremony is given on another page.

The PRESIDENT announced that Dr. M. W. Travers was prevented by indisposition from attending and giving his paper entitled "The Changes in the Early Stages of the Melting of Glass Batches."

The SECRETARY was instructed to express to Dr. Travers the Society's regret at his absence, and its best wishes for his speedy recovery.

The PRESIDENT addressed the meeting on the subject of "The Present State of the Glass Industry in Czechoslovakia," basing his remarks on a recent visit to that country.

A paper entitled, "The Production of Colourless Glass in Tank Furnaces, with particular Reference to the Use of Selenium," Part II, by A. Cousen, B.Sc., and Prof. W. E. S. Turner, D.Sc., was given by Mr. COUSEN, and illustrated by lantern slides.

Mr. Cousen's observations were supplemented by Prof. Turner, and a discussion followed to which there contributed Messrs. E. A. Coad-Pryor, W. J. Rees, Donald Robertson, H. W. Howes, and A. R. Sheen. Mr. Cousen replied.

Members had an opportunity of having tea together after the meeting.

The following were elected members :—

(*a*) *Collective Member.*

Messrs. Ned. Distilleerderij and Flesschenfabriek, voorheen de Forma Herman Jansen, Schiedam, Holland.

(*b*) *Ordinary Members.*

1. Paul Franzois Fornallaz.	*Manager, Technical Glass Department*, Établissements Albert Hirt et Cie, 20–22, Rue Richer, Paris (9^{e}).
2. Maurice Alexander Smith.	c/o Messrs. McKee Glass Co., Jeannette, Pa., U.S.A.
3. Josef Welz.	Wernsdorf, near Klostergrab, Bohemia.
4. William Ejnar Albert Walther.	*Chemical Engineer*, c/o Messrs. United Glass Bottle Manufacturers, Ltd., Charlton, London, S.E. 7.
5. Thomas Walter Frank Robertson.	*Artist in Stained Glass*, 7, Cambridge Street, Sheffield.

PROCEEDINGS OF THE FIFTY-SEVENTH MEETING.

HELD in University College, Gower Street, London, W.C. 1, on Wednesday, December 13th, 1922, at 2.30 p.m., the President, Prof. W. E. S. TURNER, D.Sc., in the Chair.

The PRESIDENT referred sympathetically to the death of Mr. Harry J. Powell, one of the first Vice-Presidents of the Society. Members expressed their approval of the letter of condolence which had been sent to the firm and family by standing in silence.

It was announced that the "Directory for the British Glass Industry" which the Society had in preparation, would probably be available in January and that particulars would be circulated within a week or two.

The PRESIDENT intimated that the visit to Paris which had been provisionally arranged for March, 1923, had been postponed to the end of May or the beginning of June.

A paper was read by Mr. T. TEISEN, B.Sc., entitled "Improvements in the Design of Recuperative Glass Pot Furnaces." The paper was illustrated by lantern slides and followed by a discussion to which there contributed the President, F. W. Adams, Dr. M. W. Travers, F. G. Clark, J. Connolly, E. A. Coad-Pryor, and V. H. Stott. Mr. Teisen replied.

A general discussion followed on "The Use of the Autoclave as a Method for Testing Glassware."

The subject was introduced by the following papers :—

(*a*) "Some Aspects of the Autoclave Test," by W. L. BAILLIE.

(*b*) "Some Criticisms on the Use of the Autoclave as a Method for Testing Glassware," by W. H. WITHEY, B.A.

(*c*) "Some Difficulties in the Interpretation of Autoclave Results," by Prof. W. E. S. TURNER, D.Sc., and F. W. HODKIN, B.Sc.

The last-mentioned paper was given by Prof. Turner. Others who contributed to the discussion were V. H. Stott, Dr. M. W. Travers, E. A. Coad-Pryor, E. Meigh, and F. W. Adams.

Votes of thanks were accorded to the authors of the papers presented to the meeting.

By the courtesy of the University College authorities members were able to have tea together in the College Refectory after the meeting.

The following were elected members :—

Ordinary Members.

1. Marcello Pirani, Ph.D.	*Professor of Physics*, Technische Hochschule, Charlottenburg, Berlin, and *Assistant Manager*, Studiengesellschaft für Beleuchtung, Berlin.
2. Rowland Douglas Smith, B.Ch.E.	*Chemist*, Messrs. Corning Glass Works, Corning, New York, U.S.A.

OBITUARY NOTICES.

Harry James Powell, C.B.E., B.A.

Mr. Harry Powell, C.B.E., whose death took place in his house at Dulwich, London, on Sunday, November 26th last, may truly be said to have done more than any man during the last fifty years to uphold the art of British glass craftsmanship.

Mr. Powell, coming of a family that for more than a century had carried on the Whitefriars Glass Works, inherited the love of glasswork. He undertook the management of the factory in 1873, and from that date until 1919, when he officially retired but by no means gave up interest in the craft, he devoted the whole of his energy to the advancement of the industry, both in the sphere of pure Art and of utility. Some of the finest of his productions are now on exhibition at the Victoria and Albert Museum.

It was under his direction that the first lens-front thermometer tubing was made that is now in general use for clinical thermometers throughout the world.

Mr. Powell's knowledge and skill were always at the disposal of men of science, in new manufactures, and novel applications of glasswork. In this way he greatly aided in the development of the early incandescent electric lamp, the bulbs of which were blown from flint glass tube made in the glass-works; in the production of the Dewar vacuum flask; the *X*-ray tube; Sir William Crookes's spectacle glass, and in many other directions.

At the factory, Mr. Powell's influence over his workmen was very great, and by his training the works employ some of the best craftsmen in the country. The decision of Mr. Harry was always taken by his men as the last word to be said upon any matter.

The writer, to whose lot it has fallen to continue his work and to carry through the projected removal of the glasshouse to a more convenient locality, had the honour of his acquaintance for many years and, until a few weeks before his death, the benefit of his advice and great technical experience. By him, and by many others who were in personal touch with him, his loss is keenly felt.

Although naturally of a retiring disposition, Mr. Powell found time for a good deal of public work. He was one of the judges of the glass exhibits at the Paris Exhibition in 1887, was a recognised authority on mediæval glass decoration, a contributor to the "Encyclopedia Britannica," one of the first Vice-Presidents of the Society of Glass Technology, and a member of the Glass Research Association. He was a governor of Dulwich College and Chairman of James Allen's Girls' School.

The burial was at Gerrards Cross, and the service was conducted by his brother, Dr. E. N. Powell, formerly Bishop of Mashonaland.

J. H. GARDINER.

CHAUNCEY WILLIAM WAGGONER.

Dr. C. W. Waggoner, Professor of Physics in the University of West Virginia, Morgantown, W. Va., died on October 27th from injuries suffered by being thrown from his horse. Dr. Waggoner, who was elected a member of the Society in April, had acquired a special interest in glass technology and was engaged in research work on glass for the Bureau of Standards. He was also connected, as consulting engineer, with the United States Window Glass Company.

ALFRED WILSON.

Mr. Alfred Wilson died on June 23rd last, aged seventy-one years. He was the son of the late Mr. Chas. Wilson, of Garstang, Lancashire.

His active business career was devoted chiefly to gas engineering, and he played no small part in the development of the gas producer and its application to the driving of gas engines, and for the firing of industrial furnaces of various kinds.

Mr. Wilson, who was a member of the Society of Friends, was buried at Kendal.

L. W.

VISIT TO THE WORKS OF THE PARKGATE IRON AND STEEL CO., LTD., AT PARKGATE, ROTHERHAM.

On the morning of Wednesday, November 22nd, about thirty members of the Society availed themselves of the opportunity of visiting the extensive works of the Parkgate Iron & Steel Co., and were able to see the working of the various processes from the smelting of the ore to the casting and rolling of steel ingots.

The visitors were conducted in small parties through the gas engine houses, which contained five gas-driven blowing engines supplying air at a pressure of 8 lb. per sq. in. to the furnaces throughout the works. One blowing engine alone had a capacity of 25,000 cubic feet of air per minute. Adjacent to this house were a number of Babcock boilers generating steam at a pressure of 160 lb. per sq. in. by the combustion of surplus blast furnace gas. The steam was used for various works purposes and that exhausted from the mill engines was collected and used in mixed turbo-generators, which provided the works with electric power. Of the three blast furnaces only one was in operation at the time of the visit; this was equipped with three Cowper stoves acting as regenerators. The steel furnaces were served by batteries of producers (38 in all) which were seen in operation with their coal handling and storage plant. The Siemens furnace plant, making basic steel, consisted of a mixing furnace of 400 tons capacity, a tilting furnace holding 75 tons, three of 60 tons, and seven of 50 tons. The charging and emptying of these furnaces were carried out by means of high-speed overhead cranes capable of dealing with ladles containing as much as 25 tons of liquid steel. The casting of a steel ingot was watched, and then the plate and rolling mills were seen in operation, with their continuous gas-fired reheating furnaces.

Members taking part in the visit were very well pleased with everything they saw, and with the excellent organisation of the works as a whole. Many were astonished at the cleanliness and orderly appearance of all the shops and yards.

A hearty vote of thanks to the Parkgate Iron & Steel Co. was passed at the general meeting in the afternoon.

VISIT TO THE GENERAL ELECTRIC COMPANY'S GLASS WORKS AT WEMBLEY.

On Thursday, December 14th, the day following the December meeting, a large party of members had the pleasure of visiting the new glass works of the General Electric Company at Wembley.

The party was met by Mr. C. Wilson (Managing Director of the firm) and Mr. W. W. Warren (the manager of the works). On being conducted through the works, members were first shown the batch weighing, mixing, and conveying plant, consisting of hoppers containing dry batch materials with mouths over a receiver on a weighing machine table, a rotating mixer into which the weighed materials are delivered, and a continuously moving bucket conveyor carrying the mixed batch from a covered well below the mixer to a storage bin on an upper floor.

The glass melting furnace, which was working very satisfactorily, was of the Hermansen type, with 12 covered pots. From some of the pots tube was being drawn by hand, while from others glass was ladled into a side furnace containing one large pot of special design feeding a Libbey-Owens tube-drawing machine. At the time of the visit this machine was working excellently, and members were very interested in watching its operation, as well as in the automatic weighing and gauging of the cut lengths of tube and the rejection of any that were not of correct size and weight.

The general spaciousness of the whole works was much admired.

Towards the close of the visit members were provided with refreshment, and while gathered for this purpose, Prof. Turner took the opportunity, on behalf of the members, of thanking the General Electric Co., Mr. Wilson, and Mr. Warren in particular, for their kindness in throwing their works open to the Society.

Both Mr. Wilson and Mr. Warren replied.

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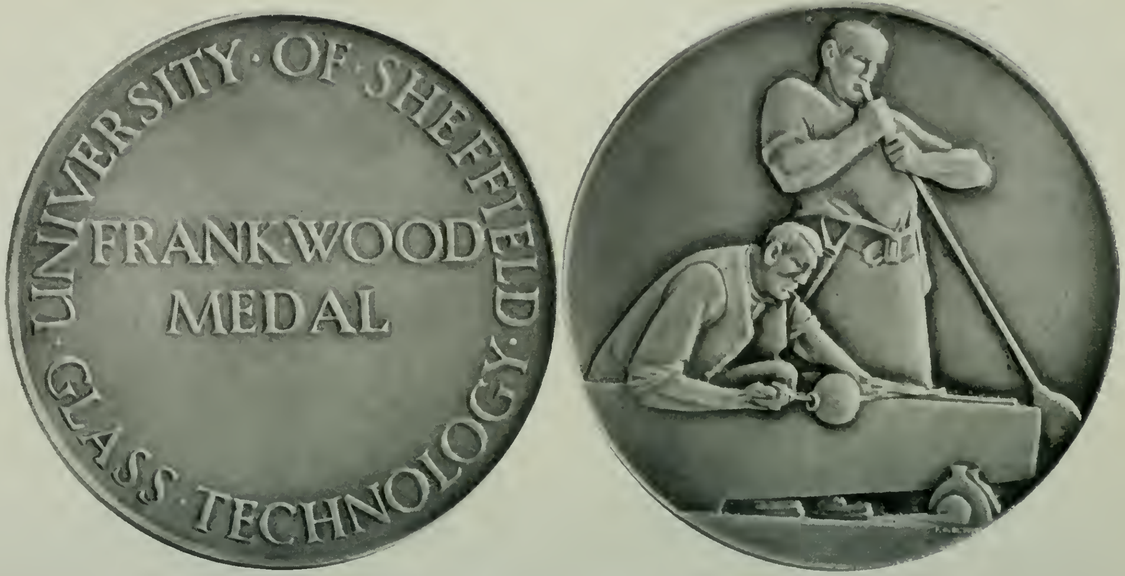

Frank Wood Medal. Obverse and Reverse.

[*To face page* 49.

PRESENTATION OF THE FRANK WOOD MEDAL.

At the meeting of the Society held in Sheffield on November 15th, the Frank Wood Medal which had been subscribed for by members of the Society in 1919 to commemorate the services of Mr. Wood to the industry, was presented to two students who in 1921 and 1922 respectively had gained it.

The President, in introducing the matter, said that the ceremony about to take place was one of great interest both to the Society and to the University of Sheffield. In one way, the ceremony was a University function, since the award of the Medal was put into the hands of the University, and he was very glad to say that the Registrar of the University, Mr. W. M. Gibbons, was present that afternoon. He would like to express the Society's cordial welcome to Mr. Gibbons. He (the President) rather thought it was the first meeting at which they had had the pleasure of Mr. Gibbons's presence. If for that reason, therefore, he was not very well known to some members, he would like to say that Mr. Gibbons in his capacity as Secretary of the Glass Research Delegacy had done great things in advancing the cause of glass technology. Some of the members of the Society had some knowledge of that work, and would bear him out in the statement as to how exceedingly hard Mr. Gibbons had laboured to carry forward the cause of glass technology.

The President then asked Mr. Gibbons to take charge of the presentation ceremony.

Mr. Gibbons said he was very much obliged to the President and to the Society for the very cordial welcome given to him. They at the University liked to think that the Society of Glass Technology was born in the University, and they regarded it as a daughter. He need scarcely say that whenever the Society wanted to meet within the University walls it would always receive a very hearty welcome. As Prof. Turner and most members of the Society knew, the University had a very warm regard for the study of Glass Technology. During the war, inspired by the initiative and the devotion of Prof. Turner, they had set up a department which had grown from small beginnings until it had become necessary to transfer it to the works at Darnall. They were quite satisfied that, with the assistance of members of the Society and of the industry at large, their courage and hope (and the removal to Darnall required both) would be fully justified.

He would now come to the main object of his presence there. He understood that in 1919 the Society determined to recognise the services of Mr. Frank Wood, services which he rendered in connection with the foundation of the Society. The Society, in order to commemorate those services, handed over to the University a cheque for a hundred guineas with the condition that the income therefrom should be utilised for some reward to students in the Glass Technology Department. It was decided that the reward should take the form of a medal, to be associated with the name of Mr. Frank Wood, in whose honour it was established. The University now held that money as trustee ready for the purpose, and they might take it that every year there would be a medal available.

It seemed only fitting that the first award, or rather the delivery of the first medal, should be made on some occasion when the Society, which founded the medal, could take part.

It also seemed appropriate that the person to hand over the medals to the successful candidates on behalf of the University, should be their friend Mr. Frank Wood. They, at the University, had learned to have great regard and affection for Mr. Wood since his association with the Glass Technology Department. He was modest and always ready to help.

The medal had taken some little time to prepare. They had asked the assistance of Prof. Rothenstein, the Principal of the Royal College of Art, South Kensington, who had a very high reputation. He entrusted the work to one of his students, Mr. Percy Metcalfe, and those who had seen the medals would, he felt sure, be satisfied that they had a very artistic production. He had seen many academic medals in his time, but never anything to excel the present medal. It was very rich and very dignified. He would call on Mr. Frank Wood, on behalf of the University, to present these medals to the successful students, and in so doing, he would like to say to Mr. Wood that the medal would be a permanent memorial of the appreciation by the University of his work for Glass Technology, and of the esteem in which he was held by his colleagues.

Mr. Frank Wood said he really felt that he was being shown a very great honour indeed, and it made him feel rather embarrassed. Very kind words had been said by Mr. Gibbons, but they all knew that when the Society was started in 1916 they very soon got a band of workers together, and the real enthusiast, of course, was Prof. Turner. Prof. Turner, they all knew, had been the backbone of the institution. At the same time, he felt most touched when he heard a sum of money had been subscribed by the members in acknowledgment of the work he had done, and for the beautiful rose-bowl which was also given to him at the same time. Whenever he felt a bit downhearted—and at times things in the glass industry had been difficult—he was greatly cheered and encouraged as he looked at that rose-bowl and remembered that it stood for a backing of real friendship from so many people. The founding of the medal was also a great honour to him. He must cordially congratulate Mr. Metcalfe on the beautiful design. He thought it an excellent medal and rather wished he was going to have one himself.

He would like to congratulate the two young men who had won it. He hoped they would have many happy years to keep it, and remind them of days gone by when they worked very hard to win it.

There was one little word of advice he might give to the two young men. He had not the pleasure of knowing them intimately, but would like to say that when they went out into the works they would find they would get on much better when conducting any investigations or trying any experiments if they would take the workmen absolutely into their confidence. He thought that was the best advice he could give to them.

The medals were then presented to Mr. G. G. Middleton, B.Sc.Tech., the winner in 1921, and Mr. H. W. Howes, B.Sc.Tech., the winner of the medal in 1922.

Mr. Gibbons then added that, after the wish expressed by Mr. Wood, the University would see that he got a medal.

TRANSACTIONS

LIST OF ABBREVIATIONS EMPLOYED IN THE JOURNAL.

Abbreviated Title.	Journal.
Amer. J. Sci.	American Journal of Science.
Analyst	The Analyst.
Ann. Physik	Annalen der Physik.
Ann. Physique	Annales de Physique.
Ber.	Berichte der Deutschen chemischen Gesellschaft.
Ber. Deut. physikal. Ges.	Berichte der Deutschen physikalischen Gesellschaft.
Bull. Soc. d'encouragement pour l'Ind. Nat.	Bulletin de la Société d'encouragement pour l'Industrie Nationale.
Bull. Geol. Soc. America	Bulletin of the Geological Society of America.
Chem. News	Chemical News.
Chem. Zeitung	Chemiker Zeitung.
Compt. rend.	Comptes rendus hebdomadaires des Séances de l'Académie des Sciences.
Deut. Mech. Zeitung	Deutsche Mechaniker-Zeitung.
Elektrotech. Zeitsch.	Elektrotechnische Zeitschrift.
Geol. Mag.	Geological Magazine.
Glashütte	Die Glashütte.
Glasindustrie	Die Glasindustrie.
J. Amer. Chem. Soc.	Journal of the American Chemical Society.
J. Geol.	Journal of Geology.
J. Ind. Eng. Chem.	Journal of Industrial and Engineering Chemistry.
J. Physical Chem.	Journal of Physical Chemistry.
J. pr. Chem.	Journal für praktische Chemie.
J. Russ. Phys. Chem. Soc.	Journal of the Physical and Chemical Society of Russia.
J. Soc. Chem. Ind.	Journal of the Society of Chemical Industry.
J. Washington Acad. Sci.	Journal of the Washington Academy of Sciences.
Ker. Rundschau	Keramische Rundschau.
Kolloid-Zeitsch.	Kolloid-Zeitschrift.
Mon. Scient.	Moniteur Scientifique.
Optician	The Optician and Scientific Instrument Maker.
Phil. Mag.	Philosophical Magazine.
Phil. Trans.	Philosophical Transactions of the Royal Society of London.
Phys. Review	Physical Review.
Physikal. Zeitsch.	Physikalische Zeitschrift.
Proc. Inst. Chem.	Proceedings of the Institute of Chemistry.
Proc. Phys. Soc.	Proceedings of the Physical Society of London.
Proc. Roy. Soc.	Proceedings of the Royal Society.
Quart. J. Geol. Soc.	Quarterly Journal of the Geological Society.
Sprechsaal	Sprechsaal.
Tonind. Zeit.	Tonindustrie-Zeitung.
Trans. Amer. Cer. Soc.	Transactions of the American Ceramic Society.
Trans. Amer. Illum. Eng. Soc.	Transactions of the American Illuminating Engineers' Society.
Trans. Cer. Soc.	Transactions of the Ceramic Society.
Trans. Farad. Soc.	Transactions of the Faraday Society.
Trans. Optical Soc.	Transactions of the Optical Society.
Zeitsch. analyt. Chem.	Zeitschrift für analytische Chemie.
Zeitsch. angew. Chem.	Zeitschrift für angewandte Chemie.
Zeitsch. anorg. Chem.	Zeitschrift für anorganische Chemie.
Zeitsch. Elektrochem.	Zeitschrift für Elektrochemie.
Zeitsch. Instrumentenkunde	Zeitschrift für Instrumentenkunde.
Zeitsch. physikal. Chem.	Zeitschrift für physikalische Chemie, Stöchiometrie und Verwandtschaftslehre.

S K . . . . Seger Cone.

All temperatures are expressed on the Centigrade scale.

I.—*The Melting of Glass.*

General Discussion at the Leeds Meeting, November 16*th,* 1921.

Editorial Introduction.

As a useful departure from the ordinary procedure at meetings of the Society, the Council decided that at the November meeting questions should be invited from members relating to any point of difficulty or matters of interest in connection with the Melting of Glass. It was felt that a meeting of this character would stimulate discussion and perhaps lead many of the usually silent members to take part. This hope was, in fact, abundantly fulfilled.

Of the many questions sent in only seven could be discussed in the time at the disposal of the meeting. The questions and the whole of the discussions were fruitful, not only to the manufacturer, but also to the technical worker and investigator in indicating how many are the problems yet to be solved before we can satisfactorily outline the scientific phenomena occurring during the operation of melting, whether in pot or tank furnaces. The discussion, therefore, had a dual usefulness.

The Casing of Glass.

The first question dealt with was couched in the following terms :—"We are interested in the casing of opal on flint glass. We believe that trouble is at times found in the cracking of the glass after manufacture. What are the special points to be observed so as to carry out the process successfully ? "

Mr. W. Butler referred to difficulties in the production of opal-cased flint glass.

Dr. M. W. Travers recalled that during the war he was actively identified with the manufacture of light hollowware. He was specially interested, therefore, when he visited the United States some time ago, in the glassworkers' methods there. While in the States he directed particular attention to the Bohemian method of producing this type of ware. He spent many hours watching the men making this light hollowware, including opal-cased globes.

One point that struck him particularly was that the men worked at very large chairs; each man had a very restricted task to perform, and discharged it with great exactitude. The men were all highly skilled, but each operated in a very limited field. In the case of a flint glass globe with an opal casing, he noticed that the first man merely gathered the ball of flint, and this performance was speedy and accurate. He handed it to the second man, who covered it with opal very uniformly and with equal rapidity. On the exactitude and speed of these first two operations all further success depended. On a perfectly uniform covering of the clear flint by the opal glass depended uniformity of light transmission, as well as uniformity of stress all over the surface. There must be no serious differences of contraction, however, between the two glasses. If the coefficients of the two glasses differed markedly, naturally they would refuse to stick together. There was a very old and well-tried method of testing whether or not two glasses had the same coefficient of expansion, namely, one that was described in the last number of the Society's JOURNAL. Two rods of glass were heated up and welded together. A thin strip of glass was obtained by pulling out the welded portion with forceps, the two glasses thus forming opposite sides of the strip. If the strip were now allowed to cool, it would bend towards the glass having the higher total expansion up to the softening point of the softer glass. A very slight curvature would indicate that the two glasses would weld together without subsequent fracture if well annealed, whereas an appreciable curvature would seem to show that the two glasses could not satisfactorily be used in combination. The manufacture of flint-and-opal glass was very largely a matter of trial and error, but he thought a good many of the difficulties might be overcome by adopting careful and active methods of working.

PROF. W. E. S. TURNER said that he thought Dr. Travers had broadly covered the ground. He was of the opinion, however, that the casing of one glass by another was more or less possible even where there was a certain amount of deviation in expansion. The degree of relative softness of the metals—the plasticity, if one liked so to call it—played a certain rôle. Some glasses might be disposed to give way much more than others. A lead glass, for instance, was particularly suitable for casing purposes. The question at issue was not only bound up with the coefficient of expansion of the flint and opal glasses, but also with the softness of the glass; and a lead glass, being softer than a calcium-containing glass, helped towards a balance of the respective coefficients. He fully agreed with the chairman that the accurate working of the metal was an important consideration in connection with the casing of glass.

Mr. J. H. Davidson mentioned that he also had been engaged in the working out of an opal-and-flint glass, and in the course of his experiments he had experienced as bad a case of cracking as it was possible to conceive. He agreed with Dr. Travers that it was largely a question of trial and error, and he might add that, by taking some of the figures for cryolite and felspar given by Mayer and Havas, glasses had been worked out which seemed to agree very well. Increased cryolite gave a distinct decrease in the expansion of the opal glass. One rather curious point had, however, arisen. They had attempted to make a thermometer glass with a white line, but when the cylinder was marvered out with the white line underneath, and this was drawn out to a length of forty or fifty yards, the white line seemed to creep round somehow. It was at the bottom at the punty end and also at the bottom at the blow-iron end, but in the middle of the sagging rope of glass tubing the white line crept round, until, when it got to the centre, it was almost at the top. The line was perfectly straight at both ends, but curved round in the middle of the rods.

Dr. Travers observed that this might be due to draught chilling.

Mr. Davidson replied that whilst this might be one explanation—indeed, that solution had already occurred to him—he could scarcely understand why the white line curled round in the centre and there only.

The Charging of Batch into Tank and Pot Furnaces.

Two questions were received relative to this subject and for convenience were considered together. They were :

(1) " What effect has the weight and volume of batch filled on and the period of time elapsing between fillings on the rate and efficiency of melting ? "

(2) " Which is the better practice to adopt in filling on batch in a glass tank, to fill on a large quantity at considerable intervals or small quantities more frequently ? "

Mr. R. L. Frink (*communicated by Prof. Turner*) said that the weight and volume of batch charged into a tank furnace had a decided effect on the efficiency of melting both from a fuel as well as a quality of glass point of view.

Assuming that two or three tons of batch were added in one charge, it was obvious that the temperature of the furnace must be greatly reduced and a greater quantity of gases would be evolved from the batch, with the result that a greater quantity of issuing gases having a lower temperature would pass through the checker work or regenerators, and as the temperature was reduced the draught would decrease. Because of the increased volume of gases and the decreased draught, there ensued a retardation of and a consequent decrease in the volume of air supplied. The result was that the rate at which the batch was melted was decreased and those components of the batch melting at lower temperatures would become, to a more or less degree, segregated.

It also followed that if the regenerators or recuperators on that side of the furnace from which the gases were issuing became lower in temperature, and if the volume of the regenerators was insufficient to meet the requirements, that particular side of the furnace would remain colder for long periods of time; consequently, for some time, the furnace was unbalanced in its combustion and unequal melting took place. This obviously would affect quality.

Again, as the colour of the glass depended on draught and combustion, it followed that there were likely to be wide variations in colour. Therefore, the amount of batch which was to be added in a given furnace and the period of time elapsing between charges could be determined by the volume of checkers as related to the amount of draught pressure or velocity of the gases passing in given periods of time.

In pot furnaces his experience led him to believe that to obtain the best results and maximum efficiency the first charge in a pot should not exceed one-third of its capacity, and it should be filled of residual glass or cullet.

A second charge should be made to fill the pot to substantially two-thirds its capacity; the third charge should be sufficient to fill the pot. In pot practice, he preferred to mix the cullet with the batch, the cullet being ground or crushed so that it would pass a 1½ inch screen. He did not agree with some that the cullet should be crushed to pass a ½ inch screen.

In tank practice he preferred first to add a charge of about 25 per cent. cullet and then to fill the batch on top. In this manner he afforded a platform which brought the batch materials up into the fire and submitted a greater area to high temperature and also permitted a more ready escape of the gases.

Dr. M. W. Travers submitted that the common practice when dealing with pot furnaces was to charge as much material into the pot as it would conveniently hold. Just how much that was would depend very largely on the nature of the glass. In the event of the glass being frothy, the second filling might have to be sparse.

At this point a member suggested that the sort of information required was not in terms of small or large quantities, but what actually would be the amount in the case of, say, a 40-ton tank? What would be the best standard practice?

Dr. M. W. Travers replied that in this matter they were dealing with a problem which affected a large number of the Society's members who were working tank furnaces of varying capacities. It would be very valuable if a number of experiments could be carried out, based on different charges at different periods of time. What the Society was anxious to obtain were trustworthy data, founded on carefully recorded tests and experiences.

Mr. R. Adamson gave it as his opinion that in dealing with a machine-operated tank furnace yielding 30 tons of glass per day, the best practice was to fill on continuously, not merely at reversal of the regenerators. In his own experience, it was probably at ten minute intervals. As long as ever they were drawing out glass he held that batch ought to be fed in continuously. The only respite that was allowed at his works in the matter of filling on was during the period that the men took their meals. They followed the practice suggested by Mr. Frink, namely, of filling on 25 per cent. of cullet, and then building up the batch on this foundation.

Mr. J. Connolly said it was also his experience that the charging in of small quantities at regular and frequent intervals was preferable to more infrequent and heavier charges. He had seen a charge thrown right across the surface of the tank—a practice which caused damage both to the colour of the glass and the brickwork. He was convinced, from personal experience, that continuous feeding at short intervals resulted not only in the production of a glass of better colour, but also in a saving of fuel.

Mr. G. Simpson observed that at his works they used to fill on every four hours, but they found that it took very considerably longer to melt the glass than when they filled on, as was now the practice, a smaller quantity every hour or half-hour.

Mr. J. Connolly remarked that when he was in the United States he noticed that the bulk of the firms filled on every twenty minutes or so.

Mr. J. H. Davidson inquired whether it was not largely a matter of the type of furnace which would decide the rate of charging. From a dog-house they could charge on large quantities without much difficulty, whereas, with an ordinary furnace there would be a lot of cold air entering the furnace every time the operation was performed.

Mr. J. Adamson expressed the view that in an open tank, without a bridge, large fillings would be better than small ones, since the latter tended to float away towards the working end.

Mr. G. Simpson here remarked that the cure for that trouble was to insert a bridge.

Mr. J. Connolly thought that a large quantity would get down to the working end quicker than a small one.

Mr. J. Adamson said he had tried both methods and his experience did not agree with Mr. Connolly's.

Prof. W. E. S. Turner said it could not be ignored that the human element still subsisted in a good many factories. Boiled down, the whole question seemed to resolve itself into whether a dog-house should or should not be employed. The inference to be drawn from what had been said was : by all means have a dog-house. He was not unaware that this question of how much should be charged on, and how often, was frequently made a matter of the convenience of the people who were doing the founding. Very often the practice had been as follows. When the charge was about to be put on, the gas pressure was reduced, which meant that instead of having a positive pressure inside the furnace there was a negative pressure. The result was that through the charge hole, which was now wide open, as well as through the working holes, there streamed in currents of cold air, which brought down the temperature. The question that had to be decided was, whether a greater benefit was obtained by putting on a large quantity and being content with slower melting, whilst having only one bad effect of cold air to contend with, than by having more rapid melting in smaller quantities but with greater frequency. The conclusion he had reached was that a dog-house avoided the difficulties of charging mentioned during the discussion. He might state that he was in a factory only three or four days previously where a dog-house had been added to an existing furnace. The cold air difficulty had been entirely dispensed with, and the owner of the factory averred that the dog-house had been his salvation. The tank, which was only a small one of about six to eight tons capacity, was now being charged on at half-hour intervals, and was giving a continuous supply of glass—much larger than ever previously, so much so that it was not only possible to have all the chairs working but an automatic machine in addition.

Discussion on this subject was brought to a close by Dr. Travers, who, summing up, said that he thought glass furnaces were very much like steam engines. In their operation quite a number of factors had to be considered, all of which were interdependent The discussion would, he thought, serve a useful purpose, even although there was not time just then to continue it to a further stage.

The Influence of Salt-cake on the Decolorising Action of Selenium.

Prof. W. E. S. Turner, in opening the discussion of this question, promised, in the first place, that the matter should be made one of research in the early future. He ventured, however, to indicate his slight experience. He knew that in batches in which selenium was used as a decoloriser, salt-cake was usually absent. At the same time, he knew of some cases where the necessary amount of salt-cake to avoid scumming was present. That amount might perhaps be 1 per cent., or, at most, 2 per cent., on the basis of the sand. Such an amount might be added without causing any serious effect on the decolorising action of the selenium. From small-scale experiments it had been ascertained that in the case of melting in which, on the one hand, only soda-ash was used, and, on the other, where a little salt-cake was employed to the extent of anything from 1 to 5 per cent. (on the basis of the sand) the decolorising effect of the selenium was certainly very distinctly diminished. He did not know that any experiments had been carried out on the possible reducing action of the selenium on sodium sulphate. Carbon, of course, naturally acted as a reducing agent on sodium sulphate. and, theoretically, sulphur might perform a similar function, if the sulphur was not volatilised before action was possible. Selenium, with a higher melting point and not quite so volatile, might possibly be a little more active in that connection.

The question was one which, he thought, might form the basis of a very interesting piece of work. Some time, if no one else had decided the matter before, his Department might find it possible to give attention to it. Whilst making these observations he must interpose a note which, he thought, disagreed with his own views. It was better that they should have disagreement in discussions of this character, for it was by disagreement that debatable points would be the more clearly elucidated.

Mr. R. L. Frink had been kind enough to send him a note bearing upon the point. Mr. Frink considered that "a small amount of salt-cake was very efficient in stabilising the colour of the glass when selenium was used, this being particularly true for furnaces operating under strongly reducing conditions. He had found that 1 to 2 per cent. of salt-cake—20 lb. of salt-cake to 1000 lb. of sand—greatly improved the colour, and assisted in eliminating the black edge which was usually found associated with soda–lime glasses that had an excess of soda. It also prevented the formation of scum. They knew already the value of salt-cake, but just how it acted they were not quite certain."

Prof. Turner went on to say that there was no doubt an advantage in adding salt-cake to a glass, because it acted as a convenient scavenger, absorbing the labels, corks, and so on, that were sometimes introduced into the batch along with the cullet. This, however, was a point that must be considered quite apart from the question of its action on the decoloriser. He thought that the latter question was one that still remained a subject for research.

Mr. J. Adamson observed that it was an acknowledged fact that a selenium glass which was subjected to excessive heat in the lehr came out with a decided tinge of pink. He could not explain what was the precise chemical action which gave rise to this, but he could state the phenomenon as a fact.

Prof. W. E. S. Turner inquired whether it was excessive selenium which gave the pink colour, or excessive annealing.

Mr. E. A. Coad-Pryor said he would like to ask Mr. Frink to amplify his statement that the sulphates stabilised the colour when selenium was used. The phenomenon relating to the change in colour during the annealing of a selenium glass was one that was subject to most minute changes. He had seen bottles piled up, and in the pile every other bottle would be pink or green. He had noticed on a small scale that when more salt-cake was present there must also be more selenium. He thought it would be comparatively easy to work out a scale determining the amount of the decoloriser to be used with varying amounts of salt-cake.

Dr. M. W. Travers, summing up the discussion, thought that the question of the change which took place in the lehr during the annealing of a selenium glass was very important, because it had been demonstrated that whilst it was possible to make a lovely coloured glass as it came from the tank, the colour was often lost in the passage of the glass through the lehr.

The Relation between Squatting or Deformation Temperature and Founding Temperature.

The question bearing on this subject was :

" If a Seger cone be made from a glass by grinding and moulding, is there any relation between the squatting point of the cone and the founding and plaining temperatures of the glass ? "

Mr. V. H. Stott said that as to whether there was a relation between the founding temperature of a glass and the squatting point of a cone made therefrom, the answer was in the negative. It might be stated roughly that the squatting point of a cone, determined with a standard rate of heating, gave the temperature at which a certain viscosity was reached. On the other hand, the founding temperature of a glass depended on a very large number of factors, many of which, such as the composition and state of division of the raw materials, the eutectics possible, and so forth, were completely independent of the properties of the finished glass.

With respect to the second part of the question in which " plaining temperature " was substituted for " founding temperature," although in general no relation existed, there might sometimes be relations in particular cases.

If they assumed that the smallest bubbles to be removed from the glass had always the same size, and that they allowed the same time for the plaining of similar sized pots of glass, then the " plaining temperature " was the temperature corresponding with a definite viscosity of the glass. This viscosity would be, perhaps, a millionth of that corresponding with the squatting point of a cone. It would be clear that as the variation of the viscosity of a glass with temperature to a marked extent depended on its composition, there would be no relation between the temperatures corresponding with so widely different viscosities. In the case of glasses differing little in composition, certain changes in composition did not change the shape of the viscosity–temperature curve, but merely had the effect of adding or subtracting a constant quantity to all the temperatures. Under such conditions the differences in temperature between the squatting points of the cones and the " plaining temperatures " would be the same for the different glasses. It was obvious that a relation so restricted had a very limited application indeed.

Mr. J. H. Davidson said that the actual squatting temperature of a Seger cone depended largely on the duration of the heating. The squatting of a cone registered heat-work efficiently, especially when the material in question was similar in composition to the cone, as was the case with pottery and clays generally, but was not a good indication of actual temperatures.

A cone made of ground glass moulded into shape with some adhesive would not be useful for controlling founding operations, since the temperature at which the cone would deform would be far below that at which the glass would be sufficiently mobile to allow of the escape of gas bubbles or to acquire homogeneity. Again, once a cone had squatted it was of no further use. It simply indicated that at some time a particular heat condition had been attained, but gave no indication, say, of a subsequent fall in temperature.

The Cause of Dark Spots in Chromium Green Glass.

The discussion on this subject was opened by Mr. J. H. Davidson, who replied to the following question :

" We are often troubled with dark specks in our actinic green glass. We use chromium oxide. What can we do to get this colour and avoid the dark specks ? "

Mr. J. H. Davidson suggested that the black specks were due to undissolved chromium oxide or chromates. Practically all actinic glasses were made from chromium as the colouring oxide. In tank furnaces, the chromium was usually added as a chromate salt, in which case good mixing and distribution of the colouring agent were readily obtained. For pot furnaces, the chromium was used in the form either of a bichromate or of chromium oxide. There was a difference in the working of these two. The bichromate was very much more fusible, so that there was less liability to the existence of infusible black specks.

In any case, when the temperature was not high enough, or when the mixture was not fine enough, the black specks would be encountered, although not quite to the same extent with the chromate as with the chromium oxide. The specks were met with both in the batch and in the cullet. If the specks were present in the cullet, and this "specky" cullet were used, it would be impossible to avoid the specks in the ultimate glass. Continuing, Mr. Davidson said that when "specky" glass was encountered in the glasshouse it was almost entirely due to the lack of temperature in the furnace, or to insufficient fineness in the colouring material. During the recent coal strike, when one had to fire with material which was only fuel by courtesy, it was almost impossible to get the requisite heat within the furnace, and this was a fact that had a particularly bad effect on the actinic green glasses made at that time. The trouble was, however, overcome by taking water-ground chromium oxide, passing it through a 150-mesh sieve, and mixing the ground chromium oxide along with a portion of the sand in the ratio of four or five pounds of the chromium oxide to thirty to forty pounds of clean dry sand. This mixture was then added to the bulk of the batch, thus distributing the colouring oxide better. In this case, even with a comparatively low furnace temperature, an absolutely clear green glass was obtained.

Mr. F. G. Clark said that in making actinic green glass in covered pots two forms of chromium were used, namely, the oxide of chromium and the bichromate of soda or potash. If the latter salt was used alone, sooner or later, owing probably to some oxidising agent such as a nitrate getting accidentally into the pot, a yellowish-green colour was produced. If the oxide alone was present there was a great danger of this salt not getting thoroughly dissolved by the alkalies, causing black specks in the glass which did not disappear after the glass was founded, however long the pot was kept stopped up. The only way of overcoming this was either (*a*) by using the green oxide in a very finely ground condition, or (*b*) by using a mixture of, say, two parts of the bichromate to one part of the green oxide. In either of these ways it was easily possible to produce a glass free from black specks, and in his (Mr. Clark's) opinion a mixture of the two forms was preferable.

Prof. W. E. S. Turner said that he had been approached many times with regard to this question of actinic green glass. It had been suggested in the discussion that the fault was largely a question of thorough admixture. It was well known that chromium oxide had a somewhat limited solubility in glass, and he remembered that Mr. J. H. Davidson had made some experiments bearing on the solubility of chromium oxide in ordinary lime–soda glass, the results of which he did not at the moment recollect.

It was common knowledge that on heating the oxides of aluminium and chromium strongly, they became insoluble in acids, and possibly this was the underlying cause of the black specks in glass. He would also like to ask if anyone had any experience of the solubility of chromium oxide in boric oxide or borax? Seeing that boric oxide was a well-known solvent for metallic oxides, might not this assist as another means of avoiding the speckiness of which complaint was made? He was aware Guertler had said that chromium oxide was almost insoluble in boric oxide, but he would like confirmation of this. He would be glad to know if any member had any experience bearing on this point.

Mr. W. Butler observed that it was his particular practice always to use a little potassium nitrate. This effectually prevented the appearance of the black specks.

Mr. F. G. Clark hereupon remarked that it all depended on the colour aimed at. If actinic green was aimed at, nitrate would not give it.

Dr. M. W. Travers in closing the discussion said that he would prefer to use bichromate of soda rather than bichromate of potash, owing to the lower cost.

The Causes of Secondary Boil.

The question which led to the discussion of this subject was as follows:

"We have sometimes noticed that metal in the tank has appeared to be quite plain and after a few hours a boil has developed. Can anyone say why this should be caused and what we can do to prevent it?"

Dr. M. W. Travers observed that they knew little about supersaturated gaseous solutions. But the existence of supersaturation was quite evident in the case of soda water or beer which had become quiescent, that is, was no longer giving off bubbles freely. If beer or soda water in this quiescent state were now stirred or shaken round, quite a considerable further evolution of gas occurred.

Even when a glass was plain, very likely it still contained gases in supersaturated solution, and this would furnish one reason why at some later stage, through change in the conditions, gas might be again evolved. They still needed very accurate observations of the conditions obtaining in a tank furnace.

Mr. F. G. Clark said that in covered pots one way in which bubbles were formed was by putting on the blower too soon after the pot was taken down, causing air to penetrate under the surface of the glass, forming bubbles which it was almost impossible to get rid of.

Mr. J. H. Davidson observed that the phenomenon was very common, both in pot- and in tank-furnaces.

Mr. J. Adamson remarked that he had known a tank quite plain at the filling on end, yet a "raw boil" developed at the working-out end. He thought it was quite a common complaint in the trade. His opinion was that some were caused by chills to the furnace, especially to particular parts of the furnace.

Mr. V. H. Stott pointed out that as a rule with ordinary liquids at room temperature, there was a temperature at which a given gas had a maximum solubility in the liquid. If the liquid were saturated at this temperature, evolution of gas might be produced either by heating or by cooling the liquid. It was well known that certain barium glasses gave off gas on cooling from certain temperatures. In view of their absolute ignorance of the solubility relationship with respect to glass at high temperatures, the existence of a temperature of maximum solubility was quite possibly one of the causes, if not the cause, of the production of bubbles in a glass by cooling.

Mr. R. L. Frink (*communicated*):

This question related to what we term a "reboil" and in tank furnace operation could be prevented or overcome by maintaining a uniform temperature gradient from the melting to the working end, or, in other words, if the glass which flowed through the bridge to the working end became reduced in temperature to any marked degree, those gases dissolved or occluded in the glass became compressed or condensed. When reheating occurred to a temperature sufficient to make them again expand, they appeared in the form of fine, round bubbles, more apparent in hot glass than cold.

Mr. Milton Asquith remarked that he often noticed a distinct small boil appear on the surface of the metal, not permanent, but sometimes the metal would be plain, then a little while afterwards boil would develop. This boil appeared when the combustion of the gas was not taking place as it should. If the gas was not clear, either through the generators not working properly or the producers making poor gas, then a smoky flame was produced and a boil appeared on the surface of the metal. With a bright clear flame, this kind of boil did not take place. It would therefore appear that the boil was caused by the carbon deposited on the surface of the glass, and when this condition was put right this boil should not develop.

Professor J. W. Cobb said that a similar phenomenon to the one described by Mr. Asquith was common in the melting of glazes, where it was known as "blistering" and by other names. There were, no doubt, several causes for it, and the explanation that it was due to difference of solubility of gases in the molten glass or glaze at different temperatures could not be accepted as a complete explanation.

He suggested that one cause common in the case of glazes would also apply to glass. If the atmosphere in the furnace was for any reason made reducing, finely divided carbon would be liable to find its way into the molten glass, and that, burning to carbon monoxide at the first access of oxygen, would give rise to bubbles of gas which would bring the glass on the boil again. In extreme cases with a discoloured glaze where the consumption of the deposited carbon had been incomplete, it was easy to see that carbon had been deposited in the substance of the glaze, and it seemed extremely likely that the same would occur with glass.

Professor Cobb went on to say that this explanation could not hold in every case, and gave in illustration some personal experiences which he had had with home-made Seger cones in the earliest days of their use.

Mr. E. A. Coad-Pryor observed that there were two or three kinds of boils. For example, boils occurred in large pots when the temperature fell; also in Owens machine working when glass was taken from the hot tank to the revolving pot. He thought the boils might be due to mechanical agitation.

Mr. F. F. S. Bryson pointed out that in several cases referred to boil had developed as a result of reheating the glass, definite instances being reheating in the revolving pot of the Owens machine and in the fore-hearth used with an automatic feeder. If, as had been suggested, the phenomenon was due simply to the differences in degree of solubility of gases in the glass at different temperatures, then in the region of the working temperature the solubility must decrease with increasing temperature, the gases being thrown out of solution on reheating. He did not think that sufficient data were available to justify this assumption.

Mr. R. Adamson referred to the practical case of a bottle made on a feeder which was plain on one side and boily on the other.

Mr. Guy Simpson remarked that gas tended to get down to the working end and might lead to boily metal.

Prof. W. E. S. Turner said that there were quite a number of different types of boil. One type arose from the presence of pieces of metallic iron dropped into the glass sometimes accidentally, sometimes deliberately. In one instance a piece of an iron rail had been deliberately placed in a tank furnace and, in other instances, gas pipe, chains, and files had been thrown in when workmen wanted to stop operation. The only cause for this boil, so far as he could see at present, was to assume that the glass held in solution small amounts of moisture which acted on the iron liberating hydrogen. Observations on the type of bubble and the kind of flame with which they burnt lent colour to this explanation, but definite proof was yet wanting of the presence of moisture.

A second type of boil arose from the use at the working end of too high a temperature. He had known such cases where too much sand was used in the batch, giving a stiff glass. Attempts to make the glass workable by raising the temperature brought about secondary boil either by expulsion of gas already in solution or by further decomposition of residual batch materials.

The third type of boil often occurred when high temperature melting followed by cooling took place. Thus, in a number of cases they found that cooling off after melting at 1350° did not result in the appearance of a boil, but melting at 1400° did.

A fourth type of boil resulted when a glass batch was used in a condition containing too much moisture, or if the cullet was wet; the glass often contained a good deal of boil or fine seed which it was almost impossible to eliminate.

The fifth type of boil occurred when there were present readily oxidisable materials. Thus, amber glass made in tank furnaces from carbon and sulphur mixture at times was troublesome when too much air was supplied to the furnace, since both these materials readily burnt out, being converted to gaseous substances. The use of such colouring materials in an Owens tank furnace was not infrequently accompanied by this trouble.

This particular type, and especially also the remarks of Prof. Cobb and Mr. Asquith, led him to make remarks about another but very similar type. Just recently, two workers * making experiments with Seger cones in a reducing atmosphere had found at temperatures round about 1000° that a hard, carbonaceous skin was deposited on the cone and remained firm even when the inner portion of the cone was fused. The skin resembled retort carbon. Clearly Mr. Asquith's observation was rather valuable in this con-

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* Bradshaw and Emery, *Trans. Cer. Soc.*, 1921–22, **21**, 107.

nection. A furnace atmosphere was not, in practice, always constant, and there were both oxidising and reducing periods. In one instance of which he (Prof. Turner) knew, powdered graphite mixed with the batch apparently remained quiescent for a time and then suddenly became oxidised, part giving a boil and part passing off as sparks.

As to the complete explanation of boil, it was also necessary to remember they had little knowledge of the conditions obtaining in a glass, and it was not all fully realised that glass represented a mass of incomplete reactions. When salt-cake was used, some remained dissolved in the glass. Possibly the amount varied according to the temperature and the time in the furnace. Just as a carbon amber glass might set up boil under oxidising conditions, so decomposition of small amounts of salt-cake might take place at higher temperatures and under reducing conditions.

II.—*The Action of Various Analytical Reagents on Chemical Glassware.*

By W. E. S. Turner, D.Sc., and T. E. Wilson, B.Sc.

(*Read at the Sheffield Meeting, January 18th*, 1922.)

The various reagents used in liquid form in chemical analysis are all comprised under one or other of the headings water, neutral aqueous salt solutions, acids and aqueous acid solutions, and alkaline solutions.

As the result of the work of a number of investigators in Germany, America, France, and in this country, and especially of the comprehensive tests carried out in this Department on modern types of chemical glassware,* much is already known about the corrosive action of water, steam, aqueous and vaporous hydrochloric acid, concentrated and dilute sulphuric acid, ammonia, sodium hydroxide, sodium carbonate, sodium chloride, and ammonium chloride solutions.

Besides these reagents, Foerster † has tested the action of concentrated and dilute nitric acid and of oxalic acid on alkali–lime–silicate chemical glassware, whilst Cowper,‡ fifty years ago, recorded tests with ammonia, sulphuretted hydrogen solution, and ammonium hydrogen sulphide solution.

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* This Journal, Trans., 1917, **1**, 153; 1918, **2**, 219.

† *Zeitsch. anal. Chem.*, 1894, **33**, 304 and 386.

‡ *Trans. Chem. Soc.*, 1882, **41**, 254.

In ordinary circumstances, the action of water and of aqueous salt solutions on a reasonably satisfactory specimen of chemical glassware is negligible during ordinary chemical analysis. Acid attack, especially that of hydrochloric acid, may be appreciable, whilst most corrosive are the alkalies.

Amongst the latter one must remember that several salt solutions, used as important analytical reagents, must be included. Sodium carbonate is such a salt. So also is sodium phosphate. Borax and potassium cyanide are further examples, although of far less general importance than sodium phosphate.

It seemed of interest, during the researches on chemical glassware made in this Department, and already published, to test the action of three additional reagents, on the newer types of chemical glassware, namely, nitric acid of specific gravity 1·2 such as is generally employed in the analysis of metals and alloys, ammonium sulphide solution which is alkaline, and sodium phosphate solution.

The glasses chosen for test were those which have in previous papers been designated as *D*, *E*, *F*, and *G*, the three former being of British make, *G* of French origin. The precise composition of each glass has been recorded in the papers already referred to. The manner of making the tests is described below and in each case the action of the reagent was repeated on the same flask three times. Round (flat-bottom) flasks of 500 c.c. capacity were used.

Action of Nitric Acid, Specific Gravity 1·2.

Two hundred and fifty c.c. of the aqueous acid were evaporated in the flask to 100 c.c. in one and a half hours. The losses in weight recorded in terms of milligrams per 100 sq. cm. were :

Glass.	*E*.	*F*.	*G*.
1st period	1·0	2·2	2·4
2nd ,, ...	1·0	1·0	1·6
3rd ,, ...	0·9	2·2	0·9
Total	2·9	5·4	4·9

The losses are comparatively small, and distinctly less than with hydrochloric acid. Indeed, as previously pointed out by us, the latter acid appears to be the one in ordinary analysis because of which care must be taken in the selection of a suitable glass for use.

Action of 2N-*Ammonium Sulphide Solution.*

This solution was made up from the concentrated ammonium sulphide reagent and its strength controlled by titration with zinc sulphate solution.

The flasks were heated in a thermostat at 100° for three hours with 150 c.c. of solution and the losses in weight in milligrams per 100 c.c. were :

Glass.	*D.*	*F.*	*G.*
1st period	1·9	2·0	2·0
2nd ,,	1·0	1·3	1·1
3rd ,,	0·1	0·4	0·2
Total	3·0	3·7	3·2

Here, again, the action is very small and no fear of corrosion need be entertained with this reagent during ordinary chemical analyses.

Action of Sodium Phosphate Solution.

Two strengths of solution were employed, namely, semi-normal and one-fourth normal. In each case 150 c.c. of the solution were placed in the flask and heated for three hours at 100°. The losses in weight are recorded per 100 sq. cm. as before.

A. *N/2-Sodium Phosphate Solution.*

Glass.	*E.*	*F.*	*G.*
1st period	3·4	2·3	5·6
2nd ,,	2·2	1·4	7·0
3rd ,,	2·8	2·3	9·4
Total	8·4	6·0	22·0

B. *N/4-Sodium Phosphate Solution.*

Glass.	*E.*	*F.*	*G.*
1st period	2·5	1·5	4·6
2nd ,,	1·3	1·4	6·4
3rd ,,	1·0	0·6	4·8
Total	4·8	3·5	15·8

It is clear that both strengths of sodium phosphate solution have a distinct, although small, corrosive action on glass. The two glasses *E* and *F* are only affected to a comparatively small extent, but glass *G* is much more readily attacked. In comparing the three glasses it is somewhat surprising to find that glass *G* was previously found quite as good, and in some respects, superior, to *E* and *F* when *N*/10-caustic soda, and 2*N*-ammonia solution were the corroding reagents. The differential corrosive action can, therefore, scarcely be ascribed to mere alkalinity. Glass *G* was previously found more susceptible than glasses *E* and *F* to the influence of sodium carbonate. Hence it would appear that the action of alkaline salt solutions and of caustic alkalies is not quite of the same type.

Compared with 2*N*-sodium carbonate solution, the attack by sodium phosphate is comparatively slight, as is seen from the following figures, which, for convenience, are reproduced from the earlier paper * :

Action of $2N\text{-}Na_2CO_3$ *for Three Hours at* 100°.

Loss in weight per sq. dcm.

Glass.	*E.*	*F.*	*G.*
1st period	28·4	29·5	34·7
2nd ,, ...	25·0	28·2	36·6
3rd ,, ...	24·6	25·7	36·8
Total	78·0	83·4	108·1

Summary and Conclusions.

(1) Tests have been carried out on three good types of chemical glassware with nitric acid, ammonium sulphide, and sodium phosphate solutions.

(2) Nitric acid of specific gravity 1·2 has only a very small corrosive action on all three glasses. Ammonium sulphide solution is on the whole still less corrosive. Both $N/2$- and $N/4$-sodium phosphate solution show a distinct attack on all three glasses, increasing with strength of solution.

(3) The corrosive action of alkaline salt solutions does not appear merely to be due to alkalinity, since glass *G*, which compares very favourably with glasses *E* and *F* when caustic alkalies are the corroding reagents, is distinctly the more readily attacked by alkaline salt solutions such as sodium carbonate and sodium phosphate.

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III.—*Solubility and Decomposition in Complex Systems.*

By GEORGE W. MOREY.

THE decomposition by water of glass and ceramic wares is a phenomenon of great practical importance, primarily because the tendency toward such a decomposition is one of the factors which sets a limit in certain directions on the compositions which we may employ. That the importance of the problem is appreciated is shown by the frequent reference to the subject in the literature of the ceramic and glass industries. It is the purpose of this paper to discuss the decomposition from the point of view of the phase rule and to indicate for the testing methods as used the limitations which result from the nature and complexity of the decomposition reactions.

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* This Journal, TRANS., 1917, **1**, 182.

Glass, ceramic bodies, and glazes are multicomponent systems, usually of a high degree of complexity, and, in addition, oftentimes are mixtures of glass and crystalline compounds. The reactions which result from the treatment of the above substances with water are, of course, highly complicated. In our discussion we will first leave out of consideration the presence of glasses, and later take up the effect of their presence.

In a system composed of water and a salt which is not decomposed by water, such as potassium nitrate, the " solubility " of the salt in water at a given temperature has a perfectly definite meaning. In such a case co-existence of three phases (salt, solution, and vapour) in a system of two components (water and salt) leaves but one degree of freedom, and the fixing of any one of the variables, namely, the temperature, the vapour pressure of the solution, or the composition of the solution, fixes the other two. This may not be true, and often is not true, in a system composed of more than two components. As an illustration, the system composed of H_2O, K_2O, and CrO_3 will be chosen. One of its components, water, is the reagent the action of which we are considering; a second, K_2O, is a common constituent of ceramic mixtures; the third may be taken, to an extent sufficient for our purpose, as resembling such oxides as SiO_2 and B_2O_3, both important to the ceramist. The 30° isotherm, as determined by Schreinemakers,* is shown in Fig. 1.

The three components, H_2O, K_2O, and CrO_3, are represented by the apices of the component triangle; points on the sides represent binary mixtures of two components, and points inside the triangle represent mixtures of the three components, the relative amounts of each at any point being indicated by its position in the diagram. The heavy line *ABCDEFGHI* represents the composition of the various solutions which may exist in equilibrium with the different solid phases at 30°. This line is made up of several intersecting curves; each curve represents a series of solutions, each series co-existing with a different solid phase, the composition of which is shown by the end points of the tie-lines such as from *H* to K_2CrO_4, *F* to K_2CrO_4, *F* to $K_2Cr_2O_7$. Compositions represented by points in the area between the H_2O apex and the heavy line *ABCDEFGHI* are unsaturated solutions; by points within the area *HG* K_2CrO_4, *FD* $K_2Cr_2O_7$, etc., are mixtures of saturated solution and the compound K_2CrO_4 and $K_2Cr_2O_7$, etc., respectively, and by points within the areas *F* $K_2CrO_4K_2Cr_2O_7$, etc., are mixtures of the compounds K_2CrO_4 and $K_2Cr_2O_7$ with the solution *F*.

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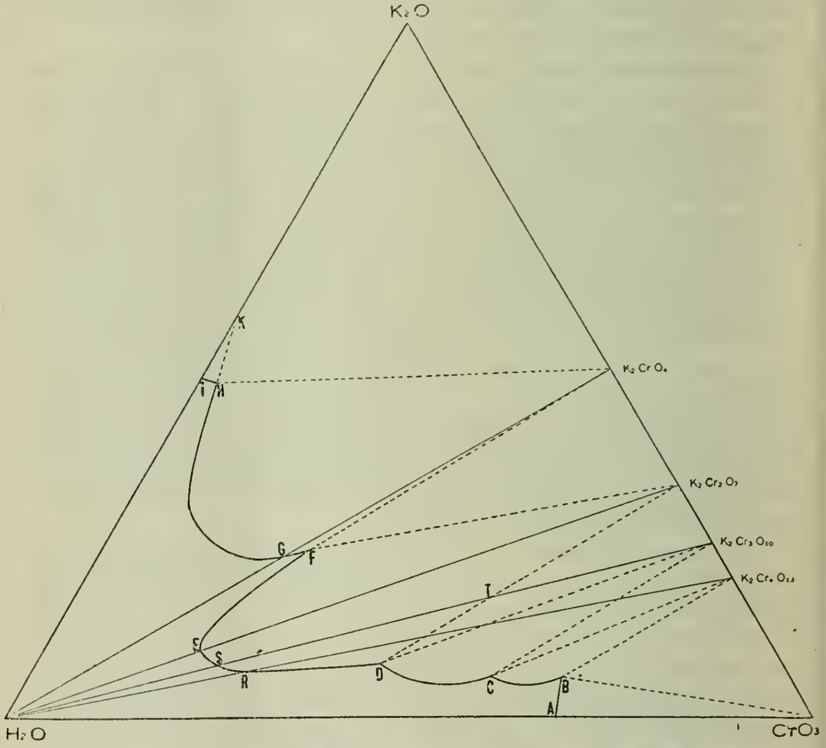
* *Zeitsch. physikal Chem.*, 1906, **55**, 71.

The solutions which can exist in equilibrium with the compound K_2CrO_4 are shown by the curve *FGH*. It will be observed that the straight line connecting the composition of the compound K_2CrO_4 with the H_2O apex cuts the curve *FGH* in the point *G*. This means that if we add water to the compound K_2CrO_4, a certain amount of solution *G* will be formed; on adding more and more water, the quantity of solution *G* will increase, and the quantity of K_2CrO_4 will decrease, until, when the mixture as a whole has the composition *G*, the solid will have disappeared. In this case the last trace of solid still has the composition K_2CrO_4, and the point *G* represents the true solubility of K_2CrO_4 in water at 30°.

Fig. 1.



The isothermal polybaric saturation curves (full lines) and the boundary curves (dotted lines) in the system H_2O—K_2O—~~SiO_2~~. CrO3

The curve *DEF* gives the composition of the solutions which can co-exist with $K_2Cr_2O_7$, and in this case also the curve is cut by the line joining H_2O and $K_2Cr_2O_7$. Point *E* gives the solubility of $K_2Cr_2O_7$ in water at 30°. It is, of course, evident that this is the only point on the curve *DEF* which represents the solubility of $K_2Cr_2O_7$ in water. Other points on the curve give the so-called "solubility" of $K_2Cr_2O_7$ in solutions containing excess of either K_2O or CrO_3, but to use the term "solubility" in this connection we must specify the composition of the solution. For this reason the entire curve *DEF* is called, not the "solubility" curve, but the "saturation" curve, of the compound $K_2Cr_2O_7$.

As the proportion of CrO_3 in the solution is increased, $K_2Cr_2O_7$ ceases to be stable, and the compound $K_2Cr_3O_{10}$ is formed, the saturation curve of which is *DC*. The line joining the composition of this compound with the H_2O apex does not cut its own saturation curve, as was the case with the two preceding compounds, but cuts the saturation curve of $K_2Cr_2O_7$ in the point *S*. In the former two cases the tie-line from H_2O to the compound remained inside the areas *HF* K_2CrO_4 and *DF* $K_2Cr_2O_7$ respectively; that is, within the areas representing complexes of solution of varying composition and the one compound. In the case of $K_2Cr_3O_{10}$, the tie-line from H_2O to $K_2Cr_3O_{10}$ passes at once into the area *D* $K_2Cr_2O_7K_2Cr_3O_{10}$, traverses this area, cuts the tie-line from *D* to $K_2Cr_2O_7$, and enters the area *DEF* $K_2Cr_2O_7$. When water is added to $K_2Cr_3O_{10}$, some of the compound is at once decomposed, forming solution of the composition *D*, and the compound $K_2Cr_2O_7$. With increasing quantity of water, the proportions of solution *D* and of compound $K_2Cr_2O_7$ increase, while the compound $K_2Cr_3O_{10}$ is continuously decomposed until, when the total composition of the mixture is represented by the point *T*, the intersection of the tie-lines from H_2O to $K_2Cr_3O_{10}$ and from *D* to $K_2Cr_2O_7$, the compound $K_2Cr_3O_{10}$ has disappeared. On further addition of water, $K_2Cr_2O_7$ passes into solution, dissolving completely when the solution has the composition *S*. Point *S* on the saturation curve of $K_2Cr_2O_7$ evidently bears no relation to the "solubility" of $K_2Cr_3O_{10}$ in water, and indeed the term "solubility" is meaningless in this connection. $K_2Cr_3O_{10}$ cannot exist in contact with liquid until the latter contains a large excess of CrO_3, the smallest amount requisite being given by the point *D*. The compounds K_2CrO_4 and $K_2Cr_2O_7$ were soluble in water without decomposition, and one point on each saturation curve gave the solubility of the compound in water. $K_2Cr_3O_{10}$ is decomposed by water, and possesses no true solubility in water.

Conditions are similar in respect to the compound $K_2Cr_4O_{13}$. Here the tie-line from H_2O to $K_2Cr_4O_{13}$ traverses the regions solution *C*-$K_2Cr_3O_{10}$—$K_2Cr_4O_{13}$, solution *C*-solution *D*-$K_2Cr_3O_{10}$, solution

D-$K_2Cr_2O_7$—$K_2Cr_3O_{10}$, and solution D-solution F-$K_2Cr_2O_7$ before it cuts the saturation curve of $K_2Cr_2O_7$. On addition of water to $K_2Cr_4O_{13}$, we first have formed a complex of solution C and the solids $K_2Cr_4O_{13}$ and $K_2Cr_3O_{10}$. Then $K_2Cr_4O_{13}$ disappears and $K_2Cr_3O_{10}$ co-exists in equilibrium with solutions changing in composition from C to D, on its own saturation curve. When the solution has reached the composition D, $K_2Cr_2O_7$ is formed, and $K_2Cr_3O_{10}$ gradually disappears until, when the total composition of the mixture lies on the line from D to $K_2Cr_2O_7$, only $K_2Cr_2O_7$ and solution are left. On further addition of water, the liquid changes in composition from D to R, at which point the last trace of solid is dissolved. Here also the compound is decomposed by, and has no true solubility in, water.

The above system brings out clearly the distinction between compounds soluble in water and compounds decomposed by water. Silicates are all decomposed by water at the ordinary temperature, and even the complex multicomponent mixtures employed in glass and ceramics probably are decomposed by water at high temperatures and pressures. The only system which has been studied at temperatures high enough to illustrate this point is the system H_2O—K_2SiO_3—SiO_2, which has been investigated up to 1000°.* Fig. 2 gives a number of isotherms in this system; along each of these isotherms the pressure changes continuously, but for the purposes of our discussion it is only necessary to state that the experiments were carried out in closed bombs, from which the water could not escape. We shall first discuss the isotherm at 285°.

At this temperature, K_2SiO_3 has a true solubility in water, represented by the end point of the saturation curve on the H_2O—K_2SiO_3 side of the diagram. The actual solid phase at this temperature is not K_2SiO_3, but its monohydrate, K_2SiO_3,H_2O. As the proportion of SiO_2 in the solution increases, the composition of the solutions in equilibrium with potassium metasilicate monohydrate follows the saturation curve until it is intersected by the saturation curve of a second compound, richer in SiO_2, potassium disilicate monohydrate, $K_2Si_2O_5,H_2O$. From the fact that the tie-line H_2O—$K_2Si_2O_5$ cuts the saturation curve of $K_2Si_2O_5,H_2O$, it follows that this compound also has a true solubility in water at 285°. With a slightly greater proportion of SiO_2 the saturation curve of $K_2Si_2O_5,H_2O$ intersects the saturation curve of a still more silicious compound, $KHSi_2O_5$, or $K_2O,H_2O,4SiO_2$.

The saturation curves at higher temperatures show how the stability regions of the different compounds change with increasing temperature. The region within which the disilicates are stable evidently shifts to higher SiO_2 content with increasing temperature, as is shown by the successive intersections of the $K_2Si_2O_5$ saturation curves with the saturation curve of $KHSi_2O_5$. The locus of these intersections, the "boundary curve," is shown by the dotted line in the figure. This boundary curve is cut by the tie-line H_2O—$K_2Si_2O_5$ at a temperature slightly below 285°, and at lower

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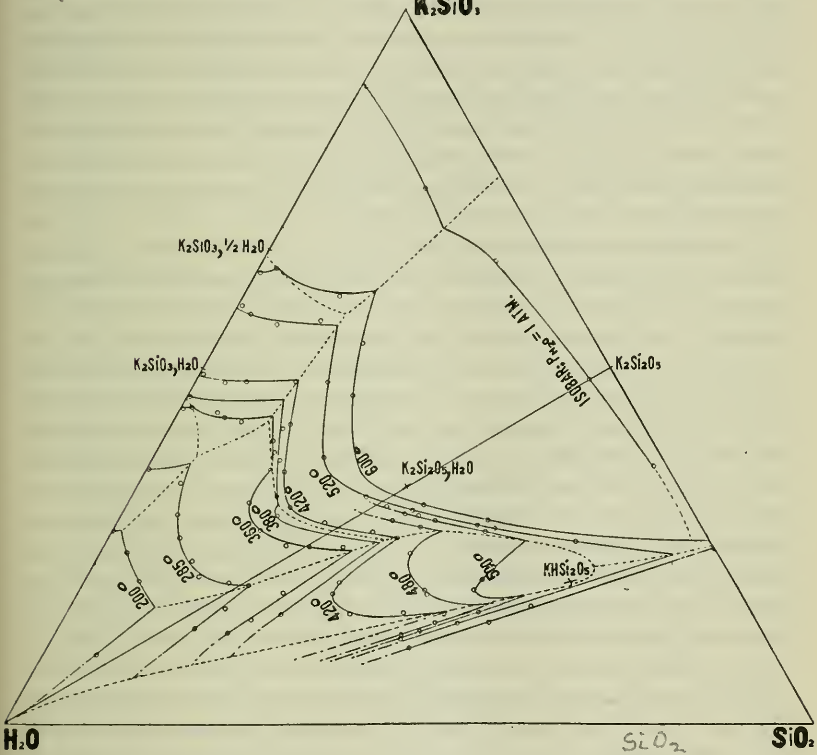
* George W. Morey, *J. Amer. Chem. Soc.*, 1917, 39, 1173.

FIG. 2.



SiO_2

Isothermal saturation curves in the system H_2O—K_2O—~~CrO_3~~ *at* 30°.

temperatures $K_2Si_2O_5,H_2O$ is decomposed by water. This is shown clearly by the 200° isotherm. The boundary curve K_2SiO_3,H_2O—$K_2Si_2O_5,H_2O$ also slopes toward the H_2O—K_2SiO_3 side of the component triangle, and at about 180° this compound also is decomposed by water.

While this system was not followed to lower temperatures, it is probable, from the general shape of all the stability fields, that at ordinary temperatures true equilibrium in any mixture of H_2O—K_2O—SiO_2 would mean a solution containing a vanishingly small amount of SiO_2, the actual amount depending on the amount of K_2O present, in equilibrium with a solid crystalline phase of pure SiO_2, or a crystalline compound of SiO_2 and H_2O, if any such exists. To be sure, " water glass solutions " containing large amounts of SiO_2 exist, but such solutions contain the SiO_2 in a colloidal condition, and bear no known relation to the true solutions, which would co-exist with crystalline phases. For example, a potassium water glass can be obtained as a viscous liquid which would not be stable as a true solution below 450—500°. The end result of treating $K_2Si_2O_5,H_2O$ with water at the ordinary temperature, if the peptisation of the silica could be prevented and true equilibrium attained, would be that practically all the SiO_2 would be left as quartz, or as a crystalline compound between SiO_2 and water, if such a compound exists, and the liquid would consist of a KOH solution containing a small amount of SiO_2. But this solution would in no sense represent the solubility of the compound in water.

This system is analogous to those obtained with complex silicates such as glasses and ceramic bodies and glazes, as well as natural minerals. When such substances are treated with water, either at ordinary temperatures or at such moderate temperatures as are obtainable in autoclaves, the compounds are decomposed, just as the potassium disilicate is decomposed, and more or less of certain constituents passes into solution. In all these cases the end result, if equilibrium were attained, would be an alkaline liquid, containing possibly small amounts of certain constituents such as B_2O_3, and vanishingly small amounts of other components, together with various crystalline phases, depending on the complexity of the original substance. In this case also the composition of the liquid would have no bearing on the " solubility " of the substance which had been decomposed, for we have seen that the term solubility has no meaning in such a case. When the decomposition is not carried to completion it is even more obvious that the use of the term " solubility " is incorrect, but such a misuse of the term is frequent. To cite but a single example, Peddle * treated a number of powdered glasses with water, titrated the filtered solution with acid, calculated the acid to its equivalent alkali, and presents a tabular summary headed, " Solubility in milligrams alkali per 100 grams of powdered glass." He further says " . . . the addition of CaO and PbO decreases the solubility in a marked degree," and, " . . . the glass containing Na_2O has a less solubility than the corresponding glass containing K_2O." It is

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* See the series of papers on the development of various types of glasses, this Journal, TRANS., 1920, **4**, 14 and 36; 1921, **5**. The quotations in the text are taken from this Journal, TRANS., 1921, **5**, 95.

better to present such results as indicating the relative resistance of the materials to the action of water or other reagent as was done by Walker and Smither.*

In the preceding it has been assumed that the substance considered was a crystalline compound, or a mixture of crystalline compounds, but ceramic substances often contain considerable proportions of glassy constituents, and the stability of glasses is often called into question. But inasmuch as the phenomenon we are considering is one of decomposition, with formation of new solid phases, the circumstance that part or all of the material is in the form of glass will have no bearing on the end result of such a decomposition. However, it will affect the rate of the decomposition, and therefore, as will be pointed out subsequently, the results observed.

In carrying out tests on the stability towards water or similar reagents, the action is rarely continued until decomposition is complete. Such a test of the resistance of silicate substances is in reality a determination of a rate of reaction, under more or less well defined conditions. The precise specification of these conditions then becomes of paramount importance, especially as rates of reaction are peculiarly susceptible to change in the experimental conditions. Attack on the material by the reagent is a surface phenomenon, and its rate will be affected not only by such factors as the temperature and the composition and strength of the solution, but also by any factors which affect the area of exposed surface of the substance under examination and the movement of solvent over it. Moreover, since the results obtained do not represent an explicitly determined quantity, such as the solubility of NaCl in H_2O at 25°, but a rate which is susceptible to changes in many factors, some it may be apparently trivial, great care must be taken to specify the details of the treatment to which the sample is subjected, and to reproduce these conditions in every detail in all experiments which are expected to be comparable with one another. This requires care in a series performed in the same laboratory by the same person; the difficulties become formidable when comparison is attempted between the results of different laboratories.

The manner in which the action of water on a silicate mixture takes place has an important bearing on the results obtained. As a rule, the surface layers only are decomposed, decomposition possibly being complete in the extreme outer layer, less and less complete in succeeding layers, and the total zone of decomposition may measure but a fraction of a millimetre in thickness. In the case of a finely ground sample, decomposition may be complete in the finest particles, while the larger ones will have a core of unaltered material. Obviously the nature of the surface remaining after extraction of the dissolved constituents exercises a profound influence on the rate of decomposition. If the surface becomes covered with a coherent layer of amorphous material, the macroscopic structure of which is similar to the original surface, decomposition will be checked, and this is probably the most favourable condition. It sometimes happens that the surface of a polished piece of glass becomes altered enough by the action of the moisture and carbon dioxide of the air so that its refractive index changes in the second decimal place without the original polish being perceptibly impaired. On the other hand, it sometimes happens that the surface layer formed is powdery or friable and scales off, leaving fresh surface exposed. All gradations between these extremes are observed. The nature of the surface formed will be altered by such factors as the ratio of liquid used to the amount of solid taken, the temperature of the experiment, and also by the presence of salts, acids, or alkali.

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* Technologic Paper No. 107, Bureau of Standards.

The method of preparation of the sample to be used is of importance. Experiments have been made on powdered material, on original fire-polished surfaces, on surfaces produced by abrasives and oftentimes polished with rouge and other material, and on freshly fractured surfaces. The two latter methods are more commonly used with glasses, the two former with ceramic materials.

With material which is but slowly affected by the action of water or solutions it is usual to increase the amount of attack by fine grinding, thereby multiplying the surface exposed. The operation of crushing and pulverising may lead to decided irregularities. It is a usual practice to pulverise the substance to a given degree of fineness. Since the surface increases rapidly as the diameter of the particles decreases, the rate of decomposition observed will depend not only on the degree of fineness of the largest particles, but also on that of the smallest; the material should always be screened so that the portion used for testing passes one size screen, and is retained on the next. Even so, in the case of hard masses, the nature of the fracture, whether obtained by crushing by impact in a steel mortar or by grinding in an agate mortar, should be considered. In addition, if the mass is not thoroughly homogeneous, the powder obtained by screening will not truly represent its average properties. The difference in the amount of glass formed, or of *sillimanite* developed, by long burning as opposed to short burning may cause an accumulation of certain materials in the coarser fraction, the rate of decomposition of which will be appreciably different from that of the more easily pulverised fraction. Also, the extent to which the process of fining in a glass has been carried, or the presence of a greater or less amount of dissolved gas in a glass, will probably be of importance.

Original fire-polished surfaces are not often used, but they offer some advantages. They suffer from the disadvantages that the surface exposed to the action of the reagent is small, and that its composition and physical state are dependent not only on the original composition of the material but also on the manner, temperature, and duration of the heat treatment to which they have been subjected. In order that comparable results may be secured, it is necessary that the preliminary treatment of all samples be the same, and that melting and firing conditions be under strict control. These factors controlled, the original fire-polished surface offers many advantages. It is convenient, its area is easily determined, and it exposes to the action of the reagent the surface exposed in service.

Two other types of surfaces are sometimes used, namely, the artificially polished surface of a lens or prism face, and a fresh surface obtained by breaking a slab of glass, as in the Mylius method used for optical glass. The first of these resembles both in its advantages and disadvantages the use of fire-polished surfaces. It's resistance will be affected by the excellence of the polish, that is, the smoothness of the surface, probably by the nature of the polishing material, and the manner of cleaning the surface is of great importance. Nevertheless, the use of polished surfaces is convenient, especially for qualitative tests. The last type of surface enumerated, that obtained by the breaking of a slab of the material, is probably the best of all. It is a clean fresh surface, which has easily measured area, and fairly represents the actual material under investigation. It is especially applicable to non-porous material such as glass, which is easily obtained in thick pieces, and which can be broken in such a manner as to give a fairly smooth flat surface.

Summary.

The action of water on complex silicate mixtures, whether crystalline or wholly or in part glassy, is one of decomposition, and the results of experiments made to determine the relative fitness of such mixtures to withstand the action of water or solutions should not be confused with the results of true solubility determinations. The results obtained by such tests represent rates of decomposition, and, because such rates of reaction are profoundly affected by experimental conditions, great care must be exercised in specifying all of these conditions and in maintaining them constant.

Geophysical Laboratory,
Carnegie Institution of Washington,
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[*Received, Feb. 6th, 1922.*]

IV.—*A Critical Examination of Methods commonly used in Determining the Durability of Glass.*

By W. E. S. Turner, D.Sc.

(*Read at the Sheffield Meeting, January* 18*th*, 1922.)

Many and various are the methods which have been proposed and employed from time to time for the comparison of the durability of glass, ranging from the rapid method of boiling glass powder in water * to the slow one of exposing slabs or cubes to the action of atmospheric air for a period of a year or more.† A number of methods were discussed in an earlier publication from the Department,‡ whilst a bibliography of the subject down to 1917 has also been published by the author.§

Since 1917, several other new, or at least modified, methods have been employed, including the boiling of glass discs in the reagent,|| the passage of water vapour over polished cubes,¶ and the heating of pieces of glass with water in sealed tubes.**

It is not the purpose of this paper to examine each of the various methods proposed, but rather those three or four which have been employed fairly generally. These methods involve (1) the testing of the surfaces of glass vessels, (2) the use of plates, discs or slabs of the glass, (3) the treatment of the glass in the form of powder, (4) the autoclave test. It is not proposed to discuss the iodoeosin test of Mylius. Von Bichowsky has found that pieces of optical glass of different composition do not give strictly comparative results when this test is applied; in any case, the method, except for optical glass, has not been widely used in this country or America, and can with advantage be replaced by some one of the processes referred to in this paper.

The Expression of Results.

Before proceeding to a discussion of the various methods of testing, some comment on the methods of expressing the result of the tests seems to be called for.

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* E. W. Hagmaier, *Met. Chem. Eng.*, 1917, **16**, 604.

† C. J. Peddle, *J. Soc. Glass Tech.*, 1920, **4**, T., 16, 40, 57, 69, 100, 101, 309, 318, 328, 357.

‡ Cauwood, English, and Turner, *J. Soc. Glass Tech.*, 1917, **1**, T., 160.

§ *Ibid.*, 1917, **1**, T., 213.

|| Cauwood, Clarke, Muirhead, and Turner, *J. Soc. Glass Tech.*, 1919, **3**, T., 228.

¶ Elsden, Roberts, and Jones, *J. Soc. Glass Tech.*, 1919, **3**, T., 52.

** Von Bichowsky, *J. Amer. Cer. Soc.*, 1920, **3**, 296.

The usual corroding agents which are employed in testing glass are water, dilute acids (particularly hydrochloric), caustic soda solution, and sodium carbonate solution. It has been demonstrated by the work of Weber and by the investigations carried out in this Department that only hydrochloric acid, of the common acids in use, has distinct corrosive action on glass. Moreover, it does not appear that salt solutions, other than those having a definite alkaline character, attack glass perceptibly, or, at any rate, to a greater extent than pure water. Hence, discussion may be confined to the four special reagents named.

The test having been carried out, the results may then be expressed in terms of (1) the loss in weight suffered by the glass either per 100 gm. of the glass used, if all of it is immersed as powder in the reagent, or per 100 sq. cm. of surface, (2) the amount of total alkali (Na_2O or K_2O) abstracted from a definite weight or definite surface area exposed, (3) the weight of the residue obtained by evaporating the solution to dryness so as to determine the total solids extracted. The residue may even be subjected to analysis.

These are not the only considerations, however, in pronouncing judgment on a glass. There must be taken into account also the discoloration produced—either etching or staining; for in normal use a glass with a stained surface may prove less convenient than one unstained, even when the latter is actually the more deeply corroded. Thus, we have previously found Pyrex * glass but little affected in appearance by the action of boiling 2*N*-caustic soda solution, although it is corroded considerably more by this reagent than are most of the other good chemical glasses on the market.

It is possible also that examination of photomicrographs of the glass surface attacked might assist in arriving at a judgment on the durability of the glass. We have attempted this in connection with tests on soda–lime † and soda–magnesia glasses. The breaking down of the glass surface is very well brought out by such observations; but owing to the amorphous character of glass it is doubtful if such a method could develop into one of such usefulness as when applied to metals.

Each of the three quantitative methods of expressing the results of test has its defects, which it may be well to set out :—

(1) *The Loss in Weight Method.*—At first sight this would appear to be a wholly satisfactory method. It could only be described as such, however, if corrosion of the glass were general and uniform, or if no secondary reaction took place. Unfortunately, corrosion is not generally uniformly distributed, as will be observed from a

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* Cauwood and Turner, *J. Soc. Glass Tech.*, 1918, 2, T., 219.

† Cauwood, Clarke, Muirhead, and Turner, *loc. cit.*

study of glass surfaces shown in photomicrographs. It will probably be influenced by the lines of flow during casting,* by cords and striæ, and possibly by differential strains. Even if these factors were removed or made negligible by care during manufacture, there still remain others largely connected with the composition of glass. Thus differential action may possibly be set up by the production of less vulnerable surface deposits resulting from initial corrosive action, soluble portions being removed and insoluble or less soluble products left behind. Such changes may result from the very nature of the hydrolysis of the silicates in glass. Cobb † referred to such films in connection with his work on the formation of silicates. Moreover, we have found, during investigations carried out in this Department after the first treatment of a glass surface with a corrosive liquid, that the corroded surface shows up in patches which only spread out uniformly after a second or third treatment.

The two great difficulties in trusting to the loss in weight as a measure of corrosion are found when testing comparatively unstable glasses. The first stage in the corrosion of glass appears to be absorption of moisture, and the second, hydration of the constituents.‡ Obviously, therefore, the glass may actually gain in weight. This is quite well known. Thus, Peddle § found several cases when studying the soda–lime glasses of the series $100SiO_2,40Na_2O,x CaO$, where x lay between 5 and 40, in which there appeared to be considerable absorption of water, causing the "loss in weight" values to be erroneous; and Mr. F. W. Hodkin, working in this laboratory, has also found similar cases.

The consequence of the hydration of the glass, if not previously indicated, is made manifest when dried, especially if the glass be warmed. The surface begins to break up and flakes and scales are detached, giving the glass when dry a frosted appearance. The analysis by Peddle of one sample of this scaly matter derived from a glass during boiling with water showed it to contain SiO_2,45; Al_2O_3, 15·0; Na_2O, 18·6; and H_2O, 19·9 per cent.

It was suggested by Peddle that these scales were associated with the formation of hydrated aluminium silicates, but one hesitates to accept this as a general explanation when such scales may be observed with various sets of glasses in which the amount of alumina is very small.

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* Cauwood, Clarke, Muirhead, and Turner, *loc. cit.*, 232.

† *J. Soc. Chem. Ind.*, 1910, pp. 69 ff.; see also discussion on paper by F. W. Branson, *ibid.*, 1918, **37**, 337T.

‡ Cauwood, Clarke, Muirhead, and Turner, *loc. cit.*; von Bichowsky, *Trans. Amer. Cer. Soc.*, 1920, **3**, 309.

§ *J. Soc. Glass Tech.*, 1920, **4**, T., 36.

In arriving at a correct estimate of the loss in weight when the scaling described takes place, the difficulty is to know how to treat the glass subsequent to the test and before the final weighing operation; for the origin of the scales is often deep-seated, and if they be removed, others generally appear if the glass is allowed to stand for a short time in a dry atmosphere, and especially if warmed. Accordingly, in such circumstances, considerable variation may be found in the loss in weight recorded as the measure of corrosion.

(2) *The Alkali Extracted from the Glass.*—The solution obtained by the corrosive action of water on practically all commercial glasses is alkaline in character, resulting from the hydrolysis of the alkaline and alkaline-earth silicates, borates, etc. Part of the alkalinity (the so-called *free* alkali) can be determined by titration, using phenolphthalein as the indicator, but part remains as alkaline silicate and possibly in some cases a little sodium carbonate or borate or even phosphate may also be present. The total alkalinity is usually determined by the aid of methyl-orange as indicator. What the relationship is between the amount of free alkali and total alkali does not appear to have been ascertained in any general way; or at any rate published. Tests carried out in this laboratory on certain chemical glasses would show that the ratio varies with different glasses.

The determination of the ratio of the free to total alkali would be of interest if carried out for series of similar glasses and also for those of widely varying composition; but whatever the result, it will be clear that it is the total alkali, if either, which must be made the basis of comparison in testing corrosion.

The fact that the alkalinity of the solution arises from hydrolysis of the silicates, etc., present in the glass suggests that as the proportion of the alkaline constituent present decreases, not only may the sensitiveness of the tests (that is, as determined by alkali extracted) seriously diminish, but comparative results may not be obtainable with glasses of widely differing composition.

Against such considerations must be set off the demonstrated fact that the presence or absence of a large proportion of alkaline constituent in the glass does determine in a very large measure the extensiveness of corrosion. Nearly all silicate glasses, if they could be made free from alkali, would be very durable, at any rate, towards water. When all this has been conceded, however, it still remains true that determination of the amount of alkali extracted could only be regarded as a precise measure of degree of corrosion if the various other basic oxides capable of being present in glass were all insoluble and non-extractable. This is not the case. Thus, under the same conditions, water extracts more alkali from soda–lime trisilicate glasses than from the corresponding ones containing magnesia.* Whether or not the alkaline solution owes any of its alkalinity to the presence of very small amounts in solution of calcium, magnesium, or other hydroxides cannot with certainty be stated. All these considerations lead inevitably to the conclusion that the determination of total alkalinity by titration with standard acid and methyl-orange as indicator cannot be accepted as a true and accurate measure of corrosion in different types of glass. For, (1) other oxides than the alkalies do exert a specific effect on durability, and (2) if small amounts of other hydroxides be present in, or derivable from, the solution, the alkalinity figures, being calculated as Na_2O, cannot be correct.

It is worth while examining the relationship between the alkalinity figures and the total loss in weight suffered by the glass on treatment with boiling water. In Table I are contained the values of the ratio *loss in weight* /Na_2O *extracted,* both being measured in terms of milligrams per 100 sq. cm. of surface exposed. The glasses are similar in type throughout the series, being the soda–lime–trisilicate glasses tested in this Department.† For convenience, the ratio is written by the symbol R.

TABLE I.

	Percentage in the glass.				Percentage in the glass.		
Glass No.	CaO.	Na_2O.	R.	Glass No.	CaO.	Na_2O.	R.
1	0·21	25·34	3·8	7	7·45	17·20	1·08
2	1·50	23·80	1·8	8	8·16	16·00	1·12
3	2·61	23·00	1·4	9	9·36	14·88	1·11
4	3·81	21·50	1·15	10	10·38	14·22	1·08
5	4·50	20·78	1·04	11	11·68	13·02	1·08
6	6·26	19·38	1·00				

The results are interesting. It will be seen that after the first three glasses the ratio becomes practically constant, and the figures would convey the suggestion that the main loss suffered is that actually due to extraction of alkali. In such case the free alkali should constitute the bulk of the total alkali. Unfortunately, information on this point is as yet unavailable. It is unlikely that, as the percentage of lime increases, the total alkalinity is maintained by the proportionate extraction of sodium and calcium hydroxides.

Table II contains data calculated from the results of Peddle ‡ for soda–lime–silicate glasses acted on by water at 80°.

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* See Dimbleby, Muirhead, and Turner, this vol., T., p. 101.

† Cauwood, Clarke, Muirhead, Turner, *loc. cit.*

‡ *J. Soc. Glass Tech.*, 1920, **4**, T., 36.

Table II.

Series $100SiO_2,40Na_2O,xCaO$. x Mols.	R.	Series $100SiO_2,20Na_2OxCaO$. x Mols.	R.
5	2·1	5	1·4
10	1·19	10	1·4
15	0·93	15	2·8
20	0·71	20	2·2
30	0·89	30	2·5
40	0·70	40	1·8

In both series, the ratios are a little irregular, but, generally speaking, they appear to decrease in the first and increase in the second series, although in the second the maximum occurs with $x = 15$ molecules. It is certainly a striking fact in the first series that the proportion of alkali extracted to total loss in weight should increase as the lime content increases, and especially as the glass becomes, as a whole, more durable. In the second series of more durable glasses it is the total loss in weight which appears relatively to increase as the lime content increases.

Finally, in Table III, the values for a series of chemical glasses of varying types are given. The data for these glasses are calculated from the measurements of Cauwood and Turner,* the reagent being boiling water, as in Table I.

Table III.

Glass.	Percentage of Na_2O.	K_2O.	R.	Glass.	Na_2O.	K_2O.	R.
K	17·56	1·38	3·0	*P*	11·76	1·40	1·9
L	11·18	0·30	2·0	*Q*	7·40	1·75	3·8
M	11·25	0·70	2·45	*R*	7·29	7·84	3·8
N	10·01	1·29	2·4	*S*	11·16	5·60	12·5
O	3·83	0·61	2·6	*T*	9·92	3·06	2·5

An inaccuracy is obviously involved in calculating the alkali extracted as all Na_2O, but allowance for this does not make the ratio more constant. An examination of the analytically determined composition of the glasses, moreover, does not indicate that the ratio depends on the relative proportions of the alkaline oxides (Na_2O and K_2O) to the alkaline-earth oxides (CaO, MgO, ZnO). The conclusion to be drawn is that the ratio varies with the nature and amount of the other constituent oxides, a conclusion which receives proof when Peddle's data for soda–lead oxide and soda–barium oxide glasses are examined.

It appears, also, that the ratio may vary according to the conditions of temperature and pressure at which the experiment is conducted. Possibly this may partly account for the differences in the ratios for Peddle's experiments and our own, although admittedly due in part to differences of composition. Data do not exist by which to test this; but undoubtedly, as we shall show, the ratio for the same glass is different for boiling water and for water and steam at 183°.

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* *J. Soc. Glass Tech.*, 1918, **2**, T., 219.

Finally, the determination of alkalinity is only readily possible when water is the corrodent. With an acid such as sulphuric acid, it is possible to determine the loss in acidity, although if boiling hydrochloric acid is used it is not possible owing to the volatility of the acid. With caustic soda and sodium carbonate the increase in alkalinity is usually only a small fraction of that of the total, so that the error is likely to be large. In the case of the carbonate, we have also found it not easy to get a satisfactory end point in the titration.

(3) *Determination of Total Matter Extracted.*—Against this method on the score of inaccuracy little can be said. Obviously the total determined by evaporating the corroding liquid will depend at any one stage on both the amount of matter extracted and in solution and on solid matter removed, whether by actual disintegration of the surface or by the action between the water and the silicates, borates, etc., resulting in scales or flakes of a new compound; or, again, there may be a gelatinous mass containing silica. It would clearly be useful if the solution, as such, could be evaporated and analysed separately from the suspended matter. The one objection to the method is the time absorbed, but it is far and away the most accurate method.

Here, again, the method would prove least manageable when the reagents were caustic or carbonated alkali. We have carried out this method with advantage in the case of hydrochloric acid.

The Advantages and Defects of Various Methods of Testing Durability.

In the introduction to this paper four forms in which the glass may be treated have been referred to, and it is these forms that it is proposed to consider.

(1) *The Testing of Glass Vessels.*—The test carried out on the surface of glass vessels is one that commends itself at first sight as being a natural one. As a general rule, the safest plan is to test vessels under conditions as similar as possible to those which will exist in normal use. Unfortunately, it is at times necessary to depart from conditions obtaining in practice in order to obtain numerical values of sufficient magnitude in a limited time so as to outweigh experimental errors.

For the purpose of testing chemical glassware, the practice both in this country and abroad has been to use flasks or beakers, preferably the former, to add to them a definite quantity of a certain reagent and to maintain the vessel and contents at a definite temperature for a definite time. Although the principle seems very easy, there are some practical difficulties. Thus, unless the vessels are of precisely the same shape and size, a given volume of the corroding reagent will cover different areas of glass surface. It is true that it is possible to measure the area covered and calculate the extent of corrosion per 100 sq. cm., but the condition to be aimed at is a constant ratio between glass surface and weight of the reacting corrodent, and this means a definite ratio between glass surface and liquid volume, which is not maintained when the shape and size of the vessel are changed.

So long as the temperature of test remains low, the conditions are not difficult to control precisely. In testing vessels at 80° or 100°, quite a common practice, it is by no means easy to maintain several comparison vessels in such a way that the liquid they contain is precisely at the same temperature. A further source of error lies in the fact that there is practically always a considerable area of the vessel, which, although not covered by liquid, is, at the high temperature, influenced by the vapour or by the liquid condensing from the vapour. If, finally, the test be carried out by boiling the liquid either with condensation or with evaporation, not only is the error just noted introduced, but the boiling of the liquid causes it to overflow, by an indefinite amount, the area covered by the original volume of quiescent solution.

In illustration of the above considerations, it may be remarked that in this Department we obtained different results for hydrochloric acid corrosion when the latter was boiled in flasks of different sizes and shapes. In beakers the extent of corrosion appeared to be somewhat less than with flasks, probably due to the readier escape of vapour without setting up a slight excess pressure or without coming into contact with glass surface.

When the liquid is not boiled or stirred by some other means, fresh portions of corroding liquid only reach the glass surface by diffusion, which is slow. In the case of corrosion by alkaline solution this factor may be important; in the case of water, however, it is probably negligible. Nevertheless, for absolute comparison of the durable quality of a sample of glass, as glass, it would appear best that the sample, of definite area and form, should be wholly immersed in a fixed volume of reagent, which should be stirred either by boiling or by mechanical means during the test. Such a method could be based on the use either of plates or of discs or of glass reduced to granular or powder form. Such tests are referred to below, but before turning to them a brief notice must be taken of the autoclave method of test.

(2) *The Autoclave Test for Durability.*—This test is employed as an alternative to treatment with boiling water with the intention of intensifying the attack and so obtaining marked action in a short period of time. It has been adopted as a standard test for chemical glassware by the Committee of the Institute of Chemistry * and has been advocated recently by Baillie and Wilson.† As the basis of a general single test on glass, however, the experience gained from investigations in this laboratory leads us to abandon it. For whilst it may be applicable to resistant chemical glasses similar in type and to such glasses as may be used for boiler gauges, there is no doubt its results do not give a true indication of the behaviour of certain classes of glass at normal pressure. Thus, glass S, ‡ an alkali–lime glass, was found to be exceptionally durable to boiling water, but at 10 atmospheres pressure it was very extensively disintegrated, whereas other glasses, containing alumina and boric oxide, whilst inferior in the boiling water test, were greatly superior when tested in the autoclave.

Mr. F. W. Hodkin, working in this Department, has found that the measure of the corrosion in the autoclave varies in an irregular manner with the pressure and the time of action. We hope to return to this subject in a separate paper, but it may be noted in passing that when the glass of composition $6SiO_2,0{\cdot}3CaO,1{\cdot}7Na_2O$ was treated with water at 4, 5 and 25 atmospheres pressure, the alkali extracted was greatest in amount at 5 atmospheres. Anomalous results have also been obtained with normally durable glasses.

Not only does the order of durability under normal pressure not necessarily correspond with that under higher pressure, but the ratio of the weight lost to the alkali liberated is very different. In Table IV this ratio is given for the same resistant glasses as are contained in Table III, the glasses being subjected to the action of water and steam for three hours (excluding time of heating up) at a temperature of 183°.

TABLE IV.

Glass.	R.	Glass	R.
L	8·0	*P*	6·7
M	10·0	*Q*	10·0
N	7·6	*R*	14·5
O	11·8	*S*	30·9

* *J. Inst. Chem.*, 1920, p. 202.

† *J. Soc. Chem. Ind.*, 1922, **40,** 448R.

‡ Cauwood and Turner, *loc. cit.*

These ratios are far higher than those in Table III and one can only conclude that the disintegrating action and the hydrolytic and solvent actions at normal pressure and higher pressures are different. Hence, the autoclave test must be used with discretion, and in any case its findings will not necessarily apply to glass used at normal atmospheric pressure.

(3) *Tests on Immersed Plates of Glass.*—Three investigations, in which the test-piece was a slab, plate, or disc, have already been published from this Department and the methods employed described.* This method of test presents several advantages over that carried out on flasks, beakers, or other vessels; for the test-piece may be wholly immersed and the errors in calculating the amount of the attack per unit area disappear. One can, at will, expose the whole piece to the action either of liquid or of vapour. We have worked with polished surfaces, and surfaces as cast. Preferably, the polished surface should be used, as, in some types of glass, casting (without pressing) leaves wrinkles which make somewhat uncertain the determination of the surface area. Moreover, the polishing should be satisfactorily carried out. In experiments carried out in this Department with plates which had been ground down but not completely polished, bigger losses in weight due to corrosion were suffered than when fully polished pieces were used. This difference is readily understood, for the ground surface clearly presented a larger area, although by how much could not be calculated.

The disadvantage of the method in practice lies simply in the time taken to prepare the test-pieces. Otherwise it may be advocated as being free from many of the objections pertaining to the use of glass vessels.

(4) *Tests based on Powdered Glass.*—The use of powdered glass for durability tests has been adopted by several workers † and in the author's laboratory a considerable number of tests have been carried out by means of it.

At first sight it might be objected that glass prepared in this way for test would expose a surface in a different condition from that produced by mechanically polishing, fire-polishing, or blowing. Such suggestions have actually been made, namely, that differences of durability might be associated with the way in which the surface had been produced. So far as the author knows, however, no one has yet proved the existence of such differences, except that Nicolardot found some differences in the order of durability towards hydrochloric acid according as a glass vessel or powder was used. Peddle, on the other hand, found that durability, as tested by exposure of the polished surface to the atmosphere for a very long period, was in practically every case the same as ascertained by treating powdered glass with water. This undoubtedly may be said for the powder method, namely, that the differential action on a glass through want of homogeneity (through cords and striæ) is likely to be practically eliminated by powdering the glass.

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* Cauwood, Turner, and Webb, *J. Soc. Glass Tech.* 1918, **2**, T. 32; Cauwood, Clarke, Muirhead, and Turner, *loc. cit.;* Dimbleby, Muirhead, and Turner, this Vol. Trans., p. 101.

† Hagmaier, *loc. cit.;* Peddle, *loc. cit.;* Nicolardot, *Comp. rend.*, 1919, **169**, 315.

The great advantage of this method lies not so much in time saved in the preparation of the test material, but in the greatly diminished length of time during which it is necessary to expose the glass to the action of the reagent in order to obtain a sufficient degree of corrosion for easy measurement. Thus, with 5—10 grams of powdered glass, even when the particles are of comparatively larger size, such as 10—20- or 20—30-mesh, it is possible to obtain a more extensive corrosion by water in one hour than by subjecting a plate of 100 sq. cm. to similar action for six hours.

The defect of the two or three previously published methods using glass powder lies in the fact that the grain size had not been sufficiently precisely defined. When a sample of glass is ground up a variety of grain sizes is obtained presenting different ratios of surface to weight or volume; and as grinding may give different results with different glasses and with different operators, screening or sieving is essential. The author takes the view that the extreme variations should not be greater than corresponds with a difference of 10-mesh. In this laboratory the sizes mainly employed have ranged from 10—20- and from 20—30-mesh. A variety of other grades is being tested, the desire being to settle on one, if possible, which may reasonably be adopted for all glasses; for obviously, whilst a poor glass will show very marked attack when the 10—20-mesh grains are boiled in water for one hour, a very resistant glass in the same time will not show sufficient loss or sufficient liberation of alkali as to reduce experimental error to a small or negligible quantity. We are inclined to consider, from results so far obtained, that grains of 40—50-mesh may prove generally suitable, the standard time being one hour and the weight of glass being the 5 grams per 250 c.c. of reagent or 10 grams per 500 c.c., but would prefer to leave open, for the present, the decision as to grain size.

If the grain size be not smaller than 20—30-mesh, it is possible to use a platinum gauze bag container of 90-mesh. Despite the apparent disparity between the above size of glass grain and wire mesh, glass sieved between 40- and 50-mesh in part gets lost through the gauze bag of 90-mesh. The reason is due to the fact that many particles of glass are needle-shaped and not granular, and whilst they will not pass through a given mesh when presented laterally they do so when presented endways. It would appear at first sight that fine grinding would be more likely to reduce differences between individual grains; but it may be said that reasonably concordant results are obtained in repeated tests on grains of 20—30-mesh.

In preparing the sample for test we have found that agitating and even brushing the material on the sieve is not always effective in removing the very fine glass powder produced, and we have, therefore, found the bag container very convenient, in that the glass which it holds can, before the experiment, be washed with a little absolute alcohol in order to remove dust and then be quickly dried and weighed. If a bag container is not available, it is quite possible, although obviously less economical, to wash the grains on the sieve. Cold water for washing will do if it be followed quickly with a little absolute alcohol. The bag container also makes the subsequent removal of the powder for weighing very convenient, whilst the boiling with bumping, so liable when a powder lies on the bottom of a vessel heated by a naked flame, is also prevented.

Failure to remove the dust from the grains may result in appreciable error in the loss of weight recorded, whilst the dust also yields much more alkali per unit weight than the larger grains.

One or two other remarks may be made in regard to the carrying out of the test. (1) It has been found that when a silica beaker is used as the reagent container, the bumping on boiling with glass powder at the bottom is but slight. (2) The solid residue after treatment may be collected and dried in a Gooch crucible. The residue frequently consists of two portions, the grains of glass and light flakes arising as the result of the process of decomposition. The latter should therefore be removed separately, as far as possible by washing with a little cold water, and not weighed with the residual glass. (3) When the glass powder is contained in a wire gauze bag, the flakes are usually found mainly in the liquid outside. For the sake of accuracy the residual glass ought to be washed free from the flakes.

A Standard Test for the Durability of Glass.

Even those who have had little practical experience in attempts to determine the durability of glass will scarcely fail, after reading this communication, to acknowledge how involved in uncertainties are practically all methods of test. It is not difficult at all by any of the methods described above to distinguish qualitatively between a good glass and a poor one; it is probable, even, that the autoclave method will, for good or durable glass, furnish a comparative measure of corrosion much the same as for normal pressure; but it is quite clear that hitherto no satisfactory general test capable of classifying all types of glass has been used. It is such a test that is needed.

In choosing a standard test of durability, it would seem wise to select one combining simplicity with accuracy, and, in the author's view, the test should be carried out either on plates or discs, or on powder.

If the former method be adopted, the plate or disc should either be cut from a blown vessel (for example, the bottom) and the edges polished; or it should be a polished plate. The total surface area should lie between 80 and 100 sq. cm., and the test-piece should be boiled suspended in a beaker of water or hydrochloric acid for six hours or in alkaline solutions for three hours, the volume (500 c.c.) of the reagent being maintained constant by a suitable condenser.*

If the second method be adopted, the glass should be powdered and sieved so that the grains are of 20—30-mesh, dust being removed as previously described. Ten grams of the powder should be boiled in 500 c.c. of the reagent (or 5 gm. in 250 c.c.) for one hour, preferably in a platinum gauze bag, the volume of reagent being maintained constant.

The extent of corrosion resulting should be determined by methods according as a works laboratory method or a precise method is required.

For the works laboratory test, the loss in weight should be determined for all the reagents and, as an additional test in the case of water, the total alkali extracted should be determined in the filtered solution obtained.

For a precision test, the solution resulting from attack by water or hydrochloric acid should be evaporated to dryness in platinum, and very gently ignited. The solution evaporated should also include any flakes which arise by corrosive action of the reagent on the glass, although, where possible, the weight of the flakes might be separately ascertained.

Of the two methods suggested, that in which glass powder is used appears to be the simpler in operation, and simplicity may well, in view of the objections which may be taken to most of the methods, be the deciding factor.

The author suggests that the matter be examined by the Glass Standards Committee of the Society and a general standard test provisionally adopted.

Department of Glass Technology,
The University, Sheffield.

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* See Cauwood, Clarke, Muirhead, and Turner, *loc. cit.*

Discussion.

Dr. Travers said that the thanks of the Society were due to Professor Turner for bringing this very important matter again before them. A very great deal of work had been carried out on the testing of glassware, and numerous methods for carrying out the tests had been devised. Some of these methods involved the use of special and expensive apparatus, and most of them were applicable only to the testing of pieces of apparatus of very limited size. The official method adopted by the National Physical Laboratory was not applicable, for instance, to the testing of a 2-litre flask or of a beer bottle.

It was very important to standardise the method of testing glass, and to make it at once applicable to all kinds of glass, and so simple that it could be carried out in any works laboratory. If such a method were adopted, we should obtain comparable results by different workers, which was not the case at the moment.

He favoured the adoption of a method involving the grinding of the glass to powder, and sieving it between limits, after the manner suggested by Professor Turner. It might be advisable to wash the powder with ether to remove dust. He would prefer to eliminate the platinum gauze basket, if that were possible, and to carry out the water test in a silica flask. The method adopted by Dr. Peddle, who ground his glass samples until the whole would pass through a 160 mesh, was open to the objection that if the process of grinding were prolonged the sample might contain an excessive quantity of very fine material. It would give consistent results with any one worker; but it might possibly give very different results in the hands of different workers.

He suggested that the matter might be referred to a committee of the Society.

Mr. Rees said he thought Dr. Turner was doing good service in bringing forward the need for a perfectly definite method of determining the durability of glass. The need for a definite method had been indicated in the paper on "The Effect of Magnesia on the Durability of Glass," since the action of water had been tested in a manner different from the other reagents. There was just one point he would like to mention. Dr. Turner referred to the possibility of using polished samples for test. The durability of a polished surface would probably be different from the natural surface of the glass. Another point which should be dealt with was the actual physical state of the glass. Was there any difference in the resistance of the glass according as it was strained or unstrained? It might be of some importance to have some direct information on this point. All these things needed consideration in arriving at a definite and early method for measuring durability.

Mr. A. Bunce said the method suggested by Dr. Travers was very similar to one which he had used for comparing the durability of chemical glasses. Only a few experiments had been made, but the results appeared to be in line with Cauwood and Turner's tests on beakers and flasks as regards the order of durability of the different glasses.

Briefly, the method used was as follows: 10 grams of 30—60-mesh glass powder were treated in a good resistance-glass conical flask of 100 c.c. capacity with 50 c.c. of the desired reagent. A number of flasks were used, so that blanks and duplicates could be run simultaneously. The flasks were fixed in a frame at equal distances from a rod which was parallel to the axis of symmetry of the flasks. The whole arrangement was then inclined at about 45°, placed in an air-oven or steam-bath, and rotated at intervals by hand, the rod being the axis of rotation. No doubt continuous mechanical rotation would be preferable. Some difficulty was experienced in washing the 30—60-mesh particles by decantation, due to small particles floating on the surface of the liquid. If filters or Gooch crucibles were used to collect these, one, of course, also collected any chemical precipitates formed, which was undesirable if the loss of weight was being taken as the index of corrosion. The use of a coarser grade powder, as in Dr. Turner's experiments, would be an advantage in this connection. Stoppered flasks were used, the stoppers being fixed loosely with a thin strip of platinum foil during the test. They served as weighing-bottles as well as reaction vessels, the glass powder being dried and weighed without removal from the flasks.

Mr. E. A. Hailwood directed attention to the possibility of something coming off the agate mortar and pestle when the glass was being ground in it, especially seeing that glass was something after the style of a diamond, and in view of the infinitesimal weights dealt with when noting the effect that chemicals have on glassware, if glass had picked up something, even although it be very small indeed, it might affect the final figures.

He certainly thought that, assuming one could get rid of this, the method of always grinding the glass to size would give a more uniform result as between one investigator and another, because when the glass was ground, assuming one had used a piece of glass including the inside and outside skin, any effect that these skins had would also be included. Care would have to be taken not to include a piece of glass which had come from a block of glass, that is, free from skin, unless, of course, all the glass was treated the same way.

He was of opinion it was necessary to test both the interior and the skin so as to provide for the effect that the annealing fumes might have on the skin, and also the paste of the moulds. He was of opinion that this would be a better way than polishing the surfaces, because when a surface of glass was polished it might pick up something from the polishing medium.

Prof. W. E. S. Turner, in replying, said it was very gratifying to have had such an interesting discussion and there was a general unanimity of opinion that a definite method of testing durability was much overdue. He therefore hoped that the Society's Glass Standards Committee would accept the invitation to consider the matter as suggested by the President. It was for this reason that he himself had not set out all the minute details for a standard test, since these details might require a little further discussion. Most of the questions which had been asked by members were answered in the more complete account in the paper itself. These questions mainly concerned the influence of annealing and of skin effect. For his own part, whilst he could readily understand that possibly such effects might exist, he had never come across any very definite experimental proof. Possibly, however, the experimental errors involved in some of the methods of testing were large in comparison with differences due to different conditions in glass surfaces. Mr. Hailwood had suggested that grinding the glass might introduce impurity from the mortar. The grinding, however, was always done in agate, and this material was exceedingly durable, otherwise chemical analysis would be distinctly affected. Moreover, any material removed would be so exceptionally fine that the dust would readily be removable during the course of the sieving and the subsequent washing preparatory to the test.

V.—*On Apparatus for Controlling the Annealing of Glassware, and on Annealing without Pyrometers.*

By F. Twyman.

(*Read at the London Meeting, December 14th,* 1921.)

This paper is an account of some apparatus for the control of annealing and for the determination of annealing temperature. Like the apparatus described in the writer's paper read before the

Society in February, 1917, it is based on the assumption that the problem of annealing glassware is simply one of the release of stress in a highly viscous liquid. It is desirable to examine how far this assumption is justified.

The annealing of glass in certain cases has effects on the physical properties of the glass other than the mere relaxation of stress. For twenty years at least, makers of optical glass have, in reporting the optical properties of particular meltings of glass to prospective purchasers, stated whether or not the measurements were made on fine annealed glass. The differences between the measurements made before and after fine annealing were greater than any differences which could result from mere stress, and if the refractive index (and most likely other properties) is thus affected by the condition of annealing, we must, when we treat the problem solely as one of release of stress, realise that the word " annealing " used in such a connection has a restricted meaning, implying simply the release of stress at the annealing temperature. We must even be prepared to conceive it possible that a mass of glass after cooling rapidly from a high temperature at which it is homogeneous may have differing properties in different regions owing to the varied rates of cooling in those regions, that heterogeneity of this kind may not be removed by heat treatment which suffices for relaxation of the stress at the upper temperatures, and that the mass of glass originally homogeneous may acquire different coefficients of expansion in different regions which will reintroduce stress on cooling down.

There is a dearth of published investigations on the modifications of the physical properties of glass due to more or less rapid cooling. Knowledge on the point is desirable, and experiments are in progress at the present time to ascertain what differences in the refractive indices of a glass are occasioned by cooling rapidly, and at what rate such differences disappear at different temperatures. But since one finds that actual glassware of diverse kinds submitted to annealing temperatures based on viscosity measurements becomes as a matter of fact well annealed (stress-free), one may without hesitation accept this class of method as free from objection as far as glassware is concerned. Throughout this paper the word " annealing " will be used to mean the removal of stress.

In the paper referred to above, the present writer pointed out that one of the most important physical quantities governing the annealing of glass was its viscosity, described an apparatus for measuring the viscosity at various temperatures, stated a formula for the change of viscosity with temperature which held for all the glasses examined, gave a quantitative meaning to the phrase "annealing temperature," and showed how to calculate the annealing temperature from these viscosity measurements.

Later on in a patent application * a method was described whereby, by observation of the total deformation of a sample of the glass under known stress, it is possible, without measurement of temperature, to state when articles of the same glass in the same furnace would be annealed; and at a later date S. English and W. E. S. Turner † described before this Society a method whereby, by observing the deflection of a rod of glass, the annealing of articles made of the same glass and heated in the same furnace can be controlled.

These and various other methods of determining annealing temperatures published in the last few years depend on a more or less precise measurement of the viscosity of the glass. With the exception of Tool and Valasek ‡ no one appears to have objected that methods based on viscosity measurements assume a knowledge of E, the coefficient of elasticity of the glass, at its annealing temperature, a knowledge which is not usually precisely available. Experience had shown that the assumption was justified in practice, and the writer knows of no case where an annealing temperature determined by his method has failed to give good results in annealing the glassware under conditions where the temperature is well controlled. Recently, however, a method has been devised likely to be more convenient, quicker, and less expensive for the glassmakers, and it has proved possible to combine a step in this direction with the removal of the theoretical difficulties inherent in the writer's earlier method, and in the subsequent variations which involve a measurement of viscosity.

The Defects in the Earlier Method.

There are two difficulties involved in determining the annealing temperature of a glass from its viscosity.

(a) The first is fundamental. If E is the modulus of elasticity and T the time of relaxation, then the viscosity is $E \times T$.§ The time of annealing at a particular temperature depends solely on the time of relaxation of the glass at that temperature and can be determined from that quantity alone, always provided the desired degree of annealing is defined first of all. But the time of relaxation at a particular temperature cannot be determined from the viscosity unless at the same time the modulus of elasticity at that temperature is known.

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* Brit. Pat. 114183, 1917.

† This Journal, TRANS., 1918, 2, 90.

‡ Bureau of Standard Papers, U.S.A., 1920, No. 358.

§ The viscosity used here and in my earlier paper is the viscosity governing the change of velocity along a streamline. If the more usual definition of viscosity be taken, E must be replaced by R, the modulus of rigidity.

That the earlier method gives results which are trustworthy in practice is due to the fact that glasses do not greatly vary their moduli of elasticity as the temperature is raised, and that a very big change of modulus of elasticity would be necessary to cause any important difference of annealing temperature.*

(*b*) The second difficulty is of a practical character. It was insisted by one of the members of the glassware trade on the occasion of the writer's previous paper that it was one thing to state a desirable temperature for annealing and another thing to achieve it in, for instance, a coke-fired furnace. This difficulty has no doubt often discouraged pyrometric control of lehrs.

In determinations of annealing temperature which are arrived at by means of measurements of viscosity, one requires first to measure the temperature at which the viscosity of the given glass has an observed value. This requires a pyrometer, and a small, easily controllable furnace. On attempting to reproduce this temperature in the annealing lehr at least one other pyrometer is required; and even then the desired temperature may prove difficult to maintain.

Since the method now to be described removes both the theoretical objection (*a*) referred to and the necessity of measuring temperatures in annealing † (together with the necessity of a preliminary experiment in a small furnace), it is hoped that it may make an effective appeal to practical glassware manufacturers.

Theory of the New Method.

The method is based like the earlier one on Maxwell's expression for the removal of stress in viscous solids. Quoting Maxwell's words :—

" A distortion or strain of some kind, which we may call S, is produced in the body by displacement. A state of stress or elastic force, which we may call F, is thus excited. The relation between the stress and the strain may be written $F = ES$, where E is the coefficient of elasticity for that particular kind of strain.

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* The investigations of Winkelmann (*Ann. Physik,* 1897, **61**, 103) show surprisingly small change of E with temperature.

† It must not be supposed that the writer advocates that the temperature of lehrs should not be controlled by pyrometers: nevertheless, he is strongly of the opinion that the " indicators " and " recorder " described in this paper would of themselves suffice to ensure good annealing in the absence of a pyrometer.

"In a solid body free from viscosity F will remain $= ES$ and

$$\frac{dF}{dt} = E\frac{dS}{dt};$$

if, however, the body is viscous, F will not remain constant, but will tend to disappear at a rate depending on the value of F, and on the nature of the body. If we suppose this rate proportional to F, the equation may be written

$$\frac{dF}{dt} = E\frac{dS}{dt} - \frac{F}{T}$$

which will indicate the actual phenomena in an empirical manner. For if S be constant,

$$F = ESe^{-\frac{t}{T}}$$

showing that F gradually disappears, so that if the body is left to itself it gradually loses any internal stress, and the pressures are finally distributed as in a fluid at rest."

Now if we define the desired state of annealing by saying that we require the stresses originally present to be reduced in a particular proportion, we may write as original stress F_0, and we then have the proportion of stress left in the glass at the end of time t

$$\frac{F}{F_0} = e^{-\frac{t}{T}}.$$

F and F_0 here represent the stresses at the high temperature, but although both alter their value on the cooling down their ratio remains constant, so that F/F_0 represents also the ratios between the final and the original stresses both at the lower temperature.

It will be seen, then, that if in annealing glass assurance is desired that F/F_0 arrives at a particular value, a knowledge of E and S is not needed, but merely that of T, the time of relaxation. Indeed, we may go further, and say that if we can observe, during the process of annealing, the proportion of stress left in the glass (compared with that present before the process commenced) from time to time, we can stop the process when that proportion has arrived at a sufficiently small fraction, say one-tenth or one-twentieth, and that nothing further is necessary.* It will be noted that when we state the problem in this latter way we are no longer relying on Maxwell's law, but merely assume that $F/F_0 = f(t)$, where $f(t)$ does not depend on the stress.

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* It is scarcely necessary to mention that we are not dealing here with the rate of cooling.

Now we cannot conveniently observe the stress F on the objects themselves during annealing.* But we can do something nearly as good. A piece of the glass required to be annealed (which piece can be of any shape and size so long as it is possible to deform it elastically by a comfortably perceptible amount) is introduced into the furnace among the articles to be annealed. It is elastically strained by a definite amount, sufficient stress being brought to bear to deform it to that extent, and is in this way brought artificially into an unannealed state. Periodically the stress is removed, and it is allowed to spring back if it will to its original shape.

As the temperature of the furnace is raised, a time will come when the test-piece does not spring back entirely, and from a record of the time during which the piece has been kept strained at a particular temperature, and the extent to which it recovers its original position, it would be possible if desired to calculate the time of relaxation at that temperature. But for practical purposes that is not necessary; for if it springs back on release by one-half its originally strained amount we know that it has been half annealed; if to one-tenth it is 90 per cent. annealed, and so on; and this is true quite independently of whether the lehr has been kept at a constant temperature during the annealing process or not. And if the test-piece, deliberately strained, is thus annealed, then the other objects which have passed through the same temperature history and were originally strained by want of annealing will become annealed simultaneously to the same degree. Several forms of apparatus have been derived from the above considerations, and are described below. Patents have been applied for covering the various modifications.

The First Apparatus.

The glass rod, A, Fig. 1, 0·10 inch diameter and 9·5 inches long, is held in a cylindrical holder, B, by means of a milled head screw, C. The holder, B, is pushed into the end of a long protecting tube, D, and is held by bayonet slots. Further down the tube is an arrangement for depressing the end of the glass rod. This consists of a small T-shaped lever, E, pivoted at the intersection of the two portions. The middle arm of the T is bent at right angles and rests on the glass rod, whilst the cross arm is joined to two controlling wires, F. The amount of depression to be given to the glass rod is limited by a convenient stop, G. The wires pass through a diaphragm or baffle, H, and thence to the end of the protecting tube outside the furnace. Here they are joined to an indicating lever, *J*, thus completing the parallelogram formed by the wires and the **T** lever previously mentioned.

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* It could, of course, be done by polarimetric observation, but that would be excessively inconvenient.

A movement given to the indicating lever, *J*, is therefore transmitted to the **T** lever by means of the wires. Behind the indicating lever is a dial, *K*, and this registers approximately zero when the glass rod is fully depressed. At the outer end it is, of course, unnecessary to make the parts of heat-resisting materials.

Mode of Using the First Apparatus.

The mode of using the apparatus is as follows. A rod of glass is drawn out into a rod of sufficient length for the apparatus, and approximately $\frac{1}{10}$ to $\frac{1}{8}$ inch diameter; the diameter of the rod is of no importance within considerable limits. The rod is broken to a suitable length, and inserted in the apparatus, which is placed in the furnace among the articles to be annealed. When the observer thinks the annealing point is being approached, he releases the strain every few minutes, and immediately he perceives any failure of the rod to recover its original position he will cause the heating to be arrested, and will soon find that the rod will be in such a condition as only to spring back the 1/20th part of its original "spring," indicating that 95 per cent. annealing has been achieved. The apparatus can also be used for determining the annealing temperature by the aid of a suitable muffle and pyrometer, but this is more conveniently done by the third or fourth types of apparatus described later.

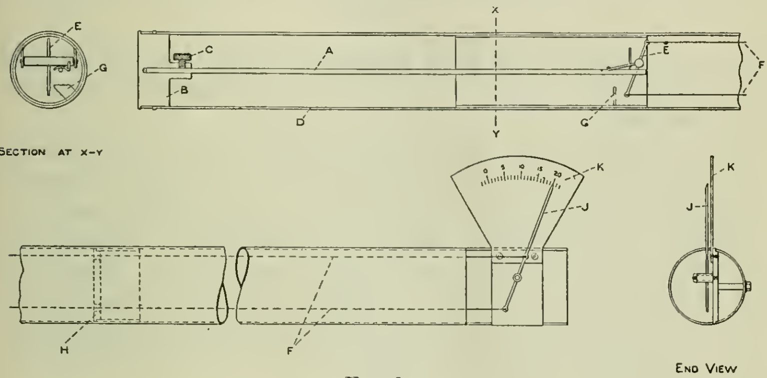

FIG. 1.

The Second Apparatus. The Annealing Recorder.

The above apparatus is not suitable for automatic lehrs, and is necessarily cumbrous. It has, however, a useful variant which will show, after the process of annealing has been gone through, whether the temperature has been sufficient, and sufficiently uniform throughout the entire height occupied by the article to be annealed. This instrument will be referred to as the annealing recorder.

A thin rod (about 1½ mm. diameter) of the glass to be annealed is drawn out as before, and placed in a small channel within a flat box (see Fig. 2) which it nearly fits, and which constrains it into an arc of a circle. The glass rod can be thrust into the channel from either end, and the box is then placed among the articles to be annealed.

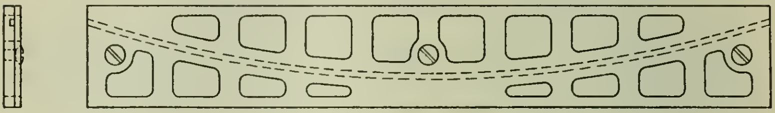

FIG. 2.

On conclusion of the annealing operation the rod is removed from the recorder, and will usually be found to spring back partly only, so that it remains somewhat curved. By a simple measurement of its curvature the degree of annealing can be found, and the heat regulation of the lehr modified accordingly. This does not, of course, give any indication during the process of annealing, and to secure such an indication in a form more conveniently than is possible with the first apparatus the third and fourth types of apparatus have been made.

The Third and Fourth Apparatus.

These forms conveniently serve two purposes. They can be used to indicate the progress of annealing within a lehr or furnace, and when so used render it possible to secure perfect annealing without the use of any kind of pyrometer. Further, if provided with the muffle and pyrometer described below they give very quickly the annealing temperature of any sample of glass. A single individual carries out the observation, and he does not require either technical training or manual skill.

Description of Principles.—The principles on which these instruments are based may be briefly described as follows. A test-piece of the substance of which the articles to be annealed are made is strained or deformed a definite amount, and, so strained, is placed with the articles in the lehr. If the constraint by which the piece is deformed were periodically removed, the proportion of the original deformation by which the test-piece would fail to spring back would indicate the percentage perfection of annealing of the articles, always assuming, of course, that the temperature of the test-piece and of the articles were the same at every stage. For instance, if the piece were to spring back, or recover its original position to the extent of only one-twentieth of its original deformation, the degree of annealing would be 95 per cent.—by which we mean that 95 per cent. of the original stress would have been removed by the annealing. So far we are only repeating what was said in describing the first apparatus.

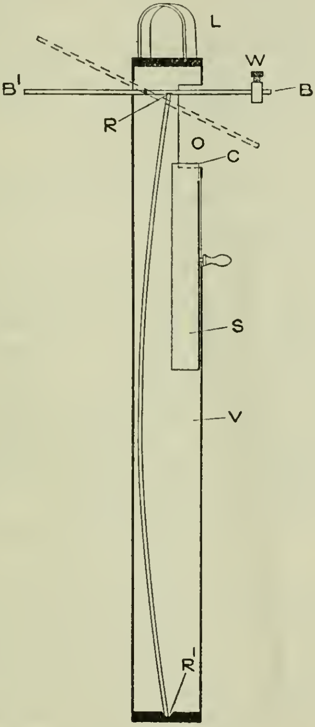

FIG. 3.

But if, instead of permitting the test-piece to spring back, we apply a constant stress of small amount in such a way as to tend to increase the original deformation, then, when the release of stress by annealing has proceeded far enough, the deformation will begin to increase continuously, and can be rendered visible in any convenient way.

Description of the Third Apparatus.

Within a cylindrical vessel, *V* (Fig. 3), is pivoted a bar, *BB′*, which extends outside the cylinder through suitable openings. The bar is balanced and pivots freely from the horizontal position to that shown by dotted lines. At the horizontal position it comes against a stop.

In the top of the box is a hole of suitable size for the introduction of a pyrometer tube when required. A metal loop, *L*, at the top serves to handle the instrument (as, for instance, to pass it, on the end of a metal rod, to any desired place within the lehr).

There is a small recess, *R*, on the under side of the bar, and another, *R′*, in the bottom of the cylinder. A loose sleeve, *S*, can be slid up the cylinder to cover the openings, and there fixed by means of the catch, *C*.

Two weights are usually supplied, a heavy and a light, which slide on the bar, and the light one can be fixed in any position as at *W* by means of a knurled screw. The heavy one with its screw is ten times as heavy as the light one.

Method of Using the Third Apparatus.

(*a*) For control of annealing.

From the material of which the articles to be annealed are made a thin rod is drawn out, about 1 mm. (say a twentieth of an inch) in diameter (the exact diameter is of no importance, nor need the diameter be exactly uniform), and a length broken off somewhat longer than the distance *RR′*.

The rod is inserted within the cylinder, and, putting the finger and thumb of the right hand through the opening *O*, the lower end of the rod is guided into the recess *R′*, whilst by bending the rod the upper end is put into the recess *R*. The spring of the rod will then keep the bar *BB′* firmly in a horizontal position against its stop.

The heavy weight is put on and shifted along the rod until it just balances the spring of the rod. The position of the weight is noted, and, replacing it by the light one, the latter is clamped in position with the milled head screw. The panel, *S*, slides into its place covering the openings, and the instrument is ready.

One or more of the instruments thus set (several are desirable, as they will reveal differences of temperature within the lehr) should now be placed among the articles to be annealed, and heating commenced. If the approximate annealing temperature is known, so much the better : fuel and time will be saved and the resultant annealing will be improved by not letting the temperature run up rapidly so as greatly to overshoot the annealing point.

When the bar *BB′ begins* to tilt annealing is *complete*. The temperature should then be lowered; not too fast at first, although after the first 70° no rate of cooling which does not fracture the articles will spoil the annealing.

Note that annealing goes on, although at a different rate, over a considerable range of temperature, and that what the instrument indicates is the completion of annealing up to the degree for which the instrument has been set, which for the weights normally supplied is for 90 per cent. perfection.

Of course, if the distribution of temperature within the lehr is not reasonably uniform, or if the articles are so stacked on top of each other that some of them are never properly heated, failure of annealing will almost inevitably result. In such case the instruments are doubly valuable, for if one instrument fails to "indicate," whilst another does, it can at once be said that there is a difference of temperature between the neighbourhood of one instrument and that of the other sufficient to be of importance in annealing.

Again, if the rod of glass when taken out and examined is found to be bent at the top only, one knows that near the floor of the lehr it has been colder than higher up by an amount which is *of importance in annealing.*

If the furnace has no pyrometer, put in an instrument with a medium weight (say four times the weight of the light one). This will give a "warning," and the temperature can then be arrested until the instrument or instruments with the light weight indicate that annealing is complete.

It should always be remembered that saving of fuel and of time and the best annealing all result from not taking the temperature unnecessarily high.

(*b*) Where the lehr is already provided with a pyrometer, it is of value to know the annealing temperature.

To do this a muffle and pyrometer are required.

After setting the instrument as described under (*a*) above, it is placed in the muffle and heated up.

The temperature at which the instrument "indicates" (that is, the temperature at which the bar tilts) will be, to a very close approximation, the annealing temperature.

If a greater accuracy is desired, the procedure is as follows. Let the temperature found by the rapid method be $A°$. A fresh rod is put in the apparatus, and heated up rapidly to the temperature of 24° lower than $A°$, keeping the temperature as constant as possible at that value.

The time in minutes is observed from the moment of attainment of this temperature until the instrument "indicates." Let this time be t.

Then

$$\frac{8 \log_{10} {}^{t/3}}{\log_{10} {}^{2}} + (A - 24)$$

is the annealing temperature. This expression depends on the observed variation with temperature of the viscosity of most glasses, and on the rule, proved by experiment, that a good working annealing temperature for glassware is that at which annealing (in this case 90 per cent. annealing) takes place in three minutes.*

The Fourth Apparatus.

This form was designed to get over certain difficulties which have been found in the practical use of the third apparatus. These difficulties were : (1) That the difference of coefficient of expansion between tube and glass rod often rendered the indications doubtful, particularly with the glasses having a high annealing temperature, since raising the temperature of the apparatus caused alteration of the strain, which it is a basic principle of the apparatus to keep constant. (2) The third apparatus is of fixed height, and cannot readily be adjusted to suit different articles. If short, its top lies below the general level of the tops of the articles to be annealed. If the articles are short, it stands well above them ; and even if it does not foul the baffles of the lehr, the upper portion which projects is usually of a considerably higher temperature than the average temperature of the articles.

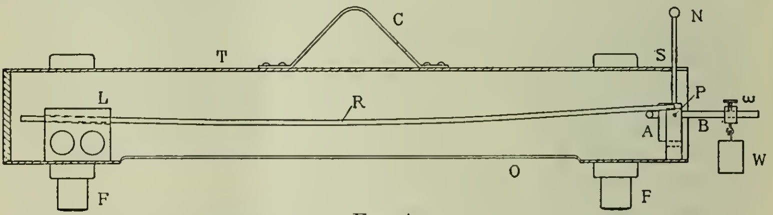

FIG. 4.

In the fourth apparatus (Fig. 4) the tube is horizontal, and the rod, instead of being bent by pressing the ends together, is bent by being loaded at one end. Within the tube, *T*, the rod, *R*, of glass, which, in the case of this instrument is about $\frac{1}{10}$ inch diameter, is fixed at one end by being placed under the loop, *L*. The other end is bent up and passed over the bent end, *A*, of the tilting bar, *B*, which tilts about the pivot, *P*. The bar carries a pointer, *N*. The pointer, *N*, comes against the stop formed by the tube at *S*, and cannot go beyond the vertical position in this direction. Thus the rod, *R*, remains strained by a constant amount. The weights, *W* and *w*, are shifted together along the bar, *B*, until they just compensate for the force exerted by the rod on A, as shown by the pointer, N, just leaving its stop, S. The small weight, w, is clamped, and the large weight, W, unhooked. W and w are so made that when w alone is in position the force exerted upwards by A is sufficient to overcome the deflection of the rod, R, due to its own weight and to impose on it in addition a force in an upward direction equal to 1/10 of the force required at A to keep the rod deflected.

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* Since annealing is not arrested when the instrument "indicates," the annealing will be in general better than 90 per cent.

The feet, F, can be unscrewed, and replaced by longer ones, so that the rod, R, occupies any desired height in the lehr. If it be at the bottom of the furnace the heat enters chiefly by an opening, O, in the bottom. If, again, it be desired to indicate the effect of heat other than at the very bottom there are similar openings made at the side. There is a loop, C, into which a rod or hook can be thrust for putting the indicator in the lehr or removing it if desired while still hot. Once the indication has been made, and the instrument has passed the hottest part of the lehr, it can, of course, be hooked out in this way so as to be used again; and thus the number of instruments required for continuous control of the lehr reduced to a limited number.

The instrument is put among the articles to be annealed, and the commencement of the tilt of the pointer, N, indicates the time when annealing is complete.

The special advantage of this type of instrument is that if the articles are tall several instruments of different heights can be put in, and the different times at which the pointers indicate will clearly show any operative differences of temperature between the bottom and higher parts of the lehr.

This apparatus, like the third, can be used with a suitable muffle and pyrometer to determine the annealing temperature, a similar procedure being adopted.

Special Forms of Annealing.

So far we have assumed that the problem of annealing is solved when all strain has been removed from the articles concerned; but this is by no means always the case. Articles such as jam jars, pasteurisation bottles, and jars for containing meats which are cooked or sterilised after packing, all have to withstand heat; and in some cases the heat is applied in such a way as to cause violent strain even in a well-annealed article. In such cases, the heat will, one would suppose, be best withstood if the object is strained in a direction contrary to the strain which will be caused in a well-annealed article of the same shape by the heat treatment to which it has to be subjected. It would appear that such an initial straining of the articles could be attained in two ways :—

(*a*) Either the object should be so strained when placed within the annealing lehr, and the annealing treatment should be such, as to remove only a portion of that strain; or, alternatively,

(*b*) The heat treatment within the lehr should be such as to remove entirely the strain in the initial stages; but the final stages of the annealing process should be so modified as to re-introduce the strain required.

Let us take the first case, and the particular case of jars which are to have hot jam poured in them. Pouring in the hot jam will cause compression of the interior surface. It is desirable that the article shall leave the annealing lehr with compression in the outer surface, and it is particularly important in the case of the bottom, since the bottom is always thicker, and since breakages are always more liable to occur at the junction between the cylindrical sides and the bottom. If we are dealing with an automatic lehr, and the jars coming from the machine are not fed too far into the lehr, and as a consequence are stood on the comparatively cold floor of the lehr, the bottom and the region in the immediate neighbourhood of the bottom will be chilled, and therefore in compression, on the outside. If, then, we insert into the lehr with these bottles an annealing indicator, which is set with such a heavy weight that it indicates when 50 per cent. annealing has been carried out, such bottles will leave the lehr with the bottom portions in compression on the outside.

In the case of a meat jar in which the sterilisation or cooking is carried out subsequent to the filling of the jar, it is desirable to have the inner layer in compression. In that case, means should be taken to chill the inner surface of the jar immediately it comes from the machine and while it is still above the annealing temperature; and again the annealing indicator should be so set that only about 50 per cent. reduction of strain occurs.

The writer has had no opportunity of observing the systematic carrying out in practice of such processes in connection with the annealing indicator; but a reasoned procedure of the kind might be expected to lead, if not to immediate success, at least towards greater certainty of result.

If it be desired to attain a specific character of strain by the second process, that, namely, of entirely annealing and re-introducing strain in the final portion of the lehr, it is obviously necessary that an indicator should be used which will give an assurance that all strain has been removed in the early part of the lehr.

Appendix.

Summary of formulæ governing the annealing of glass.

(*a*) The variation of viscosity of glass with temperature is found in the case of a large variety of glasses to be

$$\text{Mobility} = \frac{1}{\text{Viscosity}} = k \times 2^{\theta/8},$$

where k is a constant depending on the glass, and θ the temperature in degrees Centigrade. This law apparently holds for nearly all glasses in the neighbourhood of the annealing range. The relation has been substantially confirmed by Tool and Valasek,* who refer to it as "Twyman's equation."

(*b*) The law of the release of stress (Maxwell's law) in a viscous liquid is

$$\frac{F_t}{F_0} = e^{-\frac{t}{T}}$$

where F_0 is the stress in any region at time 0, F_t the stress at time t, e the base of the Naperian system of logarithms, and T the "time of relaxation." T is equal to the viscosity divided by the modulus of elasticity.

(*c*) The standard of annealing for glassware proposed in 1917 by the writer is that F_t/F_0 should be equal to or less than 1/20. This may be described as 95 per cent. annealing. The annealing temperature is defined by him as the temperature at which 95 per cent. annealing is achieved in three minutes.

Thus at the glassware annealing temperature we have

$$e^{-\frac{3}{T}} = 0{\cdot}05,$$

whence

$$T = 1 \text{ minute}.$$

(*d*) As a useful application of the above relations the time t_θ in which 95 per cent. annealing will take place at any temperature θ, being given θ_a, the annealing temperature, may be found as follows :

Assuming that E is substantially the same at the two temperatures we very easily get the relation

$$t_\theta = 3 \times 2^{-\frac{\theta-\theta_a}{8}}$$

This result may be conveniently expressed in the following table :

$\theta-\theta_a$ in °.	t_θ.
— 32	48 minutes
— 24	24 ,,
— 16	12 ,,
— 8	6 ,,
0	3 ,,
+ 8	90 seconds
+ 16	45 ,,
+ 24	22 ,,
+ 32	11 ,,

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* Bureau of Standards Scientific Papers, No. 358.

(*e*) Again, if the annealing indicator has been set to indicate at a certain percentage of annealing, it is sometimes convenient to know in what time it would indicate any other percentage. In such case, the following table should be referred to:

t = the time the articles have been in the hot portion of the lehr, which is for this purpose assumed of uniform temperature.
T = the time of relaxation of the glass when at the temperature of that hot portion.

Then from the formula (*b*) we get

Percentage annealing.	F/F_0	t/T.
95	0·05	3·0
90	0·1	2·3
80	0·2	1·6
70	0·3	1·21
60	0·4	0·92
50	0·5	0·69
40	0·6	0·51
30	0·7	0·36
20	0·8	0·22
10	0·9	0·105

As an example of the use of this table, suppose the instrument No. 4 has been set with such a weight as to "indicate" at 20 per cent. annealing; and that the indication takes place when the indicator has been within the hot portion of the lehr for three minutes. Then it will take 2·30/0·22 times as long, namely, about half an hour, for 90 per cent. annealing to be achieved.

Rough and ready as are the assumptions made in this example (namely, that the temperature of the hot portion of the lehr is uniform, and that it is possible to detect by the eye where the "hot" portion commences), it none the less forms a valuable guide as to procedure.

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DISCUSSION.

PROF. E. G. COKER said that he had been very much interested in the paper, although he knew little about glass. The experiments shown were very beautiful and he was greatly struck in noticing how stress developed. In the forms of apparatus shown a long thread of glass was used as indicator. It occurred to him that there must be some relation between the size of the thread and the size of the article being annealed. There must be a mass effect. If the article had a volume five hundred times that of the thread they might not get the correct annealing conditions. Some correction or special provision seemed to be necessary in that connection.

Mr. E. A. Coad-Pryor endorsed Prof. Coker's remarks. The difference in behaviour might be the result of the enormous difference in the heat contained. One instrument shown would be useful for exploring the temperature gradient. The lehr might in such a case almost be like a hedgehog turned inside out, with thermocouples.

Mr. R. L. Frink said that he had listened to Mr. Twyman's paper with very great interest. He thought the method suggested would be specially useful when dealing with glasses of different kinds.

Mr. V. H. Stott said that Mr. Twyman was to be heartily congratulated for introducing the principle of controlling the annealing of glass by means of a sample of the same glass. The manufacturers of porcelain had long adopted a similar principle for the firing of their ware, and with such success that the more recent introduction of pyrometers could only be regarded as an additional luxury. In connection with the annealing of glass, it could not be emphasised too strongly that the phenomena involved were extremely complicated and the use of the glass itself as an instrument of control gave promise of eliminating some of the complexities which might arise. Mr. Twyman referred to the Maxwell equations of viscous flow. It should be pointed out that Maxwell did not state that these equations held in the case of actual substances, unless certain assumptions could be shown to be true. In the case of glass, these assumptions were certainly not true at the lower temperatures of importance for annealing. For instance, Mr. Twyman spoke of the coefficient of elasticity of the glass as one of the variables in the equations. Actually, for a given type of deformation, at least two coefficients of elasticity were involved. Suppose they took a specimen of glass and imposed on it a given stress. The first effect was an abrupt deformation. This was the ordinary elastic effect and was reversible. It was, however, followed by a further reversible deformation which took place gradually and only reached its limit asymptotically. There was a third effect which consisted of a permanent viscous flow, which was irreversible. At room temperatures this was negligibly small, but of course it increased rapidly with rise of temperature. When the load was removed from a specimen of glass which had been for a long time under stress, an abrupt reduction of deformation ensued, which was equal to the original abrupt deformation. This was followed by a gradual reduction of deformation corresponding to the previous slow movement. If the temperature had been high enough to permit of viscous flow, the body would never return to its original form, as this effect was not reversible. The abrupt reversible deformations might be called elastic movements; the gradual reversible deformations might be called elastico-viscous movements, and the irreversible deformations were viscous movements.

What was the bearing of these facts on the questions of annealing? In the first place, they might define two coefficients of elasticity for a given kind of deformation, one coefficient for the elastic movement, and one determining the value of the completed elastico-viscous movement. At room temperatures, the latter was of the order of fifty or a hundred times the former (depending on the glass), which meant that the elastico-viscous movement was small. At the higher temperatures involved in annealing the two coefficients had something like equal magnitudes, although the elastic coefficient had almost the same value as at room temperature. This meant that elastico-viscous movements were of great importance at these higher temperatures. In fact, if a load were applied to glass at temperatures a little below the highest safe annealing point, the elastico-viscous flow might be for many hours faster than the viscous flow. It was clear that the relief of stress in glass was less simple than the scheme suggested by Maxwell. Let them now consider the velocity of elastico-viscous movements. They might conveniently consider the time required to move, say 99 per cent. of the total distance possible. This time depended on the nature of the glass, and was a matter of a few hours or perhaps in some cases a few days. It was greater at room temperature than at higher temperatures, but was not enormously greater, as was the viscosity. It was still at room temperature a question of hours, not years, although, of course, the actual amount of movement was much less at the lower temperature. Let them suppose that they suspended a weight on the lower end of a vertical glass rod. They then removed the weight when most of the elastico-viscous flow had taken place. The rod was strained and the strain gradually diminished, ultimately vanishing. The rod was then in its original state (if the experiment were done at room temperature, in which case there was no measurable viscous flow). In this case 99 per cent. of the strain would have disappeared in, say, a few hours. Suppose, however, instead of removing the stress after stretching, the ends of the rod were held apart at their final distance. If the temperature were high enough, the stress would gradually diminish and ultimately disappear, but at room temperature an enormous number of years would be required before 99 per cent. of the stress had disappeared. The difference was that in this case the glass was altered at the end of the experiment. It had received a permanent extension which implied viscous flow as distinct from elastico-viscous flow.

Let them consider another case. Let them imagine a rectangular rod of glass which at the beginning of the experiment was slightly curved in the shape of an arc of a circle. The glass was at room temperature and was straightened by the application of external forces. The straightening had stretched one side of the rod and compressed the other side. On releasing the forces, the rod would again become bent and would practically regain its original form in a few hours. They might, however, obtain a distribution of stress similar to that of the straightened rod by a different process. Let them begin with a horizontal straight rod at a temperature at which it was soft. Let the upper surface be maintained hotter than the lower one, so that a uniform temperature gradient existed between the two surfaces. Let both surfaces be cooled at a uniform rate down to the temperature of the room and then let the temperature of the rod become equal in all parts. The upper surface would now be in tension and the lower one in compression, the distribution of stress being identical with that of the mechanically straightened rod previously considered. It was reasonable to suppose that our heat-treated rod would behave in a similar way to the other, and would bend, reaching almost its final position in a few hours. It would then be practically free from stress. That is to say, it had been annealed at room temperature. It would be interesting to carry out this experiment. The essential point was that the stress might be relieved by a deformation such that each portion of the glass might move freely without constraint from neighbouring portions. They might therefore expect elastico-viscous movement. The phenomena in thermometry supported such a suggestion. If a thermometer which had been maintained for a considerable time at 100° were cooled quickly to 0°, and then held at the latter temperature, the volume of the bulb decreased suddenly and then went on decreasing gradually for a few hours or days in a manner quite comparable with the contraction, first by elastic movement, and then by elastico-viscous movement, of a previously stretched rod. It was clear, of course, that a simple distribution of stress such as had been considered above in the case of the heat-treated rod could not occur in the ordinary cooling of glass objects. In general the efforts of various portions of the glass to free themselves from strain were mutually opposed, and the stresses could only completely disappear through the medium of viscous flow, which at room temperatures required a very large number of years.

Enough had been said to emphasise strongly the complexity of the phenomena which might occur during the annealing of glass; and it was manifest that an instrument which, like that devised by Mr. Twyman, utilised the properties of the glass itself, had great possibilities compared with instruments which, not making use of those properties, were yet expected to cope with conditions so complicated.

Mr. S. English (*communicated*) said he had been very interested in reading through Mr. Twyman's paper. He was afraid it was difficult to agree with him in restricting the meaning of the term annealing to the removal of stress *at the annealing temperature.* Manufacturers looked on this as merely the first stage in the annealing process, and it was misleading to speak of it as if it were the whole process. From the examination of a large variety of glassware from all parts of the country, it appeared that this first stage of the process was the part most easily carried out satisfactorily and that the real difficulty in annealing glassware lay in controlling the rate of cooling. In support of this view, the figures given by Mr. Twyman for the rate of disappearance of strain could be used. In most glass houses, bottles were taken into the lehr while they still showed a dull red colour, and in the majority of cases this temperature was 40° or 50° above the annealing temperature of the glass. According to the figures given in the Appendix "*d*," if the glass were 32° above its annealing temperature 95 per cent. of the strain was removed in 11 seconds, and using the formula quoted, with glass at 40° above its annealing temperature 95 per cent. of the strain would be removed in 5·5 seconds, and at 48° above, 2·75 seconds would be sufficient to reach this degree of freedom from strain. It was thus evident that bottles deposited in a lehr still showing a red glow could not possibly retain any strain for more than a few seconds; in fact, annealing would be perfect and complete. The examination of bottles generally showed that they were partly annealed, the strained parts being either the bottoms or the thick portions of the sides. The strained bottoms might be due to the bottles having been put on to cold lehr pans, or the strain might be due to the bottoms of the bottles being comparatively thick, in which case the strain in the bottoms and the strain in the thick portions of the side was due, not to the annealing temperature not having been reached, but to the rate of cooling from the annealing temperature having been too rapid during some portion of the cooling process. It was thus possible, when using any of the four pieces of apparatus described by Mr. Twyman, that the indicator might show that the annealing temperature had been reached and practically all the strain removed at the annealing temperature and still the ware might come from the cold end of the lehr badly strained, due to the temperature gradient down the lehr being unsatisfactory, or to the passage of the ware through the lehr being too rapid. This factor was recognised when the placing of rods in lehrs was suggested in a paper from this Department,* and it was pointed out that the bending of such rods might be used in testing the temperature of the hot zone of the lehr, and thus ensuring that the annealing temperature was reached. In this connection a progressive manufacturer of optical glass wrote to him (Mr. English), a short time after the publication of the paper referred to above, with reference to the validity of a recent patent dealing with this subject, and mentioned that he had used the bending of rods in controlling the annealing of glass, but had discarded the method as useless.

On the other hand, with the present-day high-production bottle machines, bottles were stacked in close formation in lehrs while still above their annealing temperatures, and in some cases the temperature of the lehr itself due to the external supply of heat might be 20° or so below the annealing temperature of the bottles, but still the heat of the bottles themselves was radiated so slowly that they cooled down through their annealing temperature to the temperature of the lehr without the development of any appreciable strain. In such circumstances an indicator put into the lehr cold would not reach within 20° of the annealing temperature of the glass and would therefore indicate the presence of a considerable residual strain, whereas if the rate of cooling in passing down the lehr were satisfactory, the bottles would come from the cold end quite well annealed. It was thus possible for such indicators to show that strain should have been removed although the bottles might actually be found to be strained; or they might indicate a considerable residual strain and yet the bottles be quite well annealed.

On p. 54 it was stated that when all strain had been removed "the temperature should then be lowered; not too fast at first, although after the first 70° no rate of cooling which does not fracture the glass will spoil the annealing." This appeared to presume that the temperature along a lehr could be kept constant or varied at will quite easily. In practice it was not easy nor was it advisable to alter the temperature gradient down a lehr when once that gradient had been satisfactorily determined. With respect to the statement that only the first 70° of cooling must be carefully controlled, he had found in a large number of experiments on the rate of cooling of glassware, using glasses of different thicknesses, that when once all strain had been removed at the annealing temperature, it was through the range below the first 50° or 70° that the greatest care was needed. With a glass rod of a definite diameter, the maximum rate of cooling which would not cause strain to reappear during the first 50° or 70° might be 50° per hour, but during the next 100° the maximum rate of cooling would not be more than 30° per hour, and after that interval the permissible rate of cooling would again increase, and after a total drop of about 200° it would become so rapid that free cooling would not cause any permanent strain.

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* This Journal, English and Turner, Trans. 1918, 2, 94.

Mr. Twyman, replying, said, with reference to Prof. Coker's query, although naturally, during the time of rapid heating and on cooling the glass thread would not have the same temperature as a glass vessel of comparatively large mass, yet it did not seem to him likely that the rate of change of temperature in annealing lehrs during the time when the annealing process was actively proceeding would be such that operative differences of temperature would exist. Apart from the liability to such differences of temperature, the author had no reason to suppose that the rate of annealing depended on the massiveness of the article.

He had listened with great interest to the remarks of Mr. Stott. Although the notion of the phenomenon called by Mr. Stott the elastico-viscous movement was not entirely new to him in the behaviour of glass at ordinary temperatures, yet he had until now been quite unaware of the important magnitude of this effect at the temperatures used in annealing glass. If he interpreted Mr. Stott's remarks aright, the effective elastic coefficient (Young's Modulus) would (given sufficient time) at the higher temperature be reduced to one-half that at ordinary air temperature.

He hoped that if, as he gathered, Mr. Stott had data on this subject which had not previously been published, the Society might have the benefit of them. It seemed to him, however, that the apparatus he had described would, owing to the utilisation as the sensitive element of a piece of the same glass as that to be annealed, give trustworthy results notwithstanding the existence of this interesting phenomenon. On the other hand, the numerical expressions given in the appendix should be used with caution until such time as they should be proved correct by actual experiment.

In reply to Mr. English, the author regretted that he had in his paper given the impression that he confined the meaning of the term annealing to the removal of stress *at the annealing temperature*. He intended only to confine the term to the removal of stress by heat treatment. Such a restriction of meaning was necessitated by the other effects of heat treatment, such as the variations caused in (for instance) refractive index by different heat treatments.

But the author, while agreeing that the removal of stress at the annealing temperature was only the first stage of the annealing process, undoubtedly did regard it as of the very first importance. The author's own experience—admittedly confined almost entirely to the laboratory—was that the attainment of a good annealing temperature was much more than half the battle if perfect annealing were aimed at. He had had no reason to change his view that the three minute 95 per cent. rule first put forward by him in 1917 did define such a good annealing temperature. All these instruments were founded on that definition and they were therefore quantitative and not merely qualitative in their indications.

Glassware raised to or held for a brief time at such a temperature *and no higher* was unlikely to be made bad by any method of cooling likely to be applied. If, however, that temperature were greatly exceeded, or by a wide margin not attained, he could quite understand that defective annealing would result; for in the former case the cooling might be rapid throughout just the range (near the so defined annealing temperature) where very slow cooling was imperative, whilst in the latter case the annealing would never be effected at all.

In Mr. English's later remarks an illustration was chosen in which it was supposed that the lehr might be 20° or so below the annealing temperature of the bottles, but the bottles might be so hot as to cool through the annealing range without the development of appreciable strain. In such case Mr. English supposed that the indicator would attain the temperature of the lehr, and would therefore lead to an erroneous conclusion. But it seemed to the author that to suppose the existence of a lehr temperature separate from and independent of that of the bottles occupying the only portion of the lehr the temperature of which was of interest was to picture something which had no counterpart in reality.

The author's aim had been so to design the indicators and recorders that the glass rods would attain rapidly the temperature of the glass objects in their immediate neighbourhood; and such tests as he had been able to make in the laboratory showed that this aim had been fairly well achieved.

It is true that, even so, erroneous conclusions might be drawn by stacking around an indicator bottles straight from the moulding machine, and obviously much hotter than the part of the lehr where it was expected to achieve annealing, and the author thanked Mr. English for pointing out this possibility. It would be foolish to contend that erroneous conclusions might not be drawn by hasty inferences from the behaviour of these or of any instruments, but he thought that a reasoned interpretation of their indications would be of very material assistance in the process of annealing.

VI.—*An Examination and Extension of Zulkowski's Theory of the Relation between the Composition and Durability of Glasses.*

By William Learmonth Baillie.

(*Read at the Sheffield Meeting, January 18th,* 1922.)

The elucidation of the constitution of glasses, a necessary preliminary for general correlation of composition and durability, has proved to be a problem of considerable complexity. The essentials of the vitreous state preclude many experimental methods successful in other cases. Stoichiometrical proportions are seldom encountered, and glasses have therefore long been regarded as mixtures of silicates.* The inapplicability of crystallographic or melting-point data, of determining molecular weights by solution methods, or of studying chemical reactions to throw light on the constitution of glasses has narrowed investigation down, in the main, to relating the composition of glasses with their resistance to chemical reagents. The chief exception is the etching method described by Leydholt † and later employed by Jackson and Rich.‡ This has been adversely criticised by Tillotson,§ however, and its indefinite indications may probably be safely disregarded.

Benrath investigated glasses of the "crown" and "flint" types and concluded that the least reactive approximated closely to the formula $R_2O,RO,6SiO_2$; the worst glasses departed most from these proportions. He regarded any oxides present in excess of the requirements of the formula as soluble in the double silicate, possibly combined among themselves in some simple manner. The characteristic qualities of glass, namely, durability and insolubility, were attributed to its content of double silicate of the so-called "normal" formula. Probably the most important feature of this formula is its insistence on the importance of molecular equivalence of the bases of the R_2O and RO types. This equality was supported also by Weber [*] and it is interesting to note that the glass employed by Stas complied substantially with this condition [†] (see also Tables V and VI below). It was established also that "mixed" glasses are of excellent durability, provided their grouped molecular composition complies with the "normal" formula.[‡] Despite this very considerable amount of evidence in its favour, however, the formula was not without critics, and Foerster, in particular, challenged its general validity.[§]

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* Dumas, *Compt. rend.*, 1855, **40**, 321. Benrath, "Die Glasfabrikation," 1857, 25.

† *Compt. rend.*, 1852, **34**, 565.

‡ *J. Soc. Chem. Ind.*, 1901, **20**, 555.

§ *J. Ind. Eng. Chem.*, 1917, **9**, 937.

That glasses are not simply mutual solutions of alkali-silicates and alkaline-earth or other silicates appears, *a priori*, a justifiable conclusion from the difference in reactivity between such bodies and even the poorer glasses. The results obtained by Mylius and Foerster in investigations of the durability of alkali–lime–silicates constitute important confirmatory evidence of the existence of double silicates in glasses.[||]

Laboratory experiments on the formation of vitreous silicates and the examination of commercial glassware led Zulkowski to formulate a theory of the chemical constitution of glasses which is substantially an extension of Benrath's in the light of the foregoing evidence.[¶] At the same time, he advanced suggestions regarding the course of the reactions occurring during founding, and concluded that it is during the "fining" or "plaining" period that the maximum formation of double silicates is attained. He was able to explain with considerable success the various degrees of durability shown by commercial glassware in quantitative tests, employing for this purpose a method of calculation based on the analytical results. This theory and the formula employed are discussed in more detail below.

The novel and complex theory of silicate structure advanced by W. and D. Asch [**] has been applied by them to the structural formulation of glasses, and deductions regarding the durability and ease of hydration of certain glasses have been attempted. It does not, however, appear that there is any likelihood of the hexite–pentite theory admitting of application to the study of glasses in general with the simplicity and ease of Zulkowski's, even if, as appears extremely doubtful, it be justifiable to write for every or any glass a single structural formula.*

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[*] *Ann. Phys. Chem.*, 1879, **6**, 431.

[†] *Chem. News*, 1868, **17**, 1.

[‡] *Jahresber. über d. Fortschr. d. Chem. Technol.*, 1895, 742.

[§] *Zeitsch. anal. Chem.*, 1894, **34**, 381.

[||] *Ber.*, 1889, **22**, 1092. *Zeitsch. Instrumentenkunde*, 1889, **9**, 117.

[¶] *Chem. Ind.*, 1889, **22**, 280; 1900, **23**, 108, 346.

[**] "Die Silicate in chemischen und technischen Beziehung," 1911.

Zulkowski's Theory.

So far as is known, Zulkowski's is the only theory which enables a relation between the chemical composition and the general durability of glasses to be calculated from a simply-derived formula. Tscheuschner's formula, which has recently been applied to the classification of the crown glasses,† appears mathematically not unpromising. It is difficult, however, to reconcile the complex numerical relations it involves with the undoubted simplicity of the reactions occurring in glass manufacture.

Zulkowski's theory is one of chemical constitution alone, and is based, in large measure, on direct chemical evidence. It involves no conception of physical constitution except that it regards annealing as favourable to optimum durability.

It is assumed that, in founding, the primary reaction is the formation of simple silicates of the alkalies and alkaline-earths, and that the formation of double silicates occurs later. This second reaction will be the slower and will not proceed to completion unless the mass is maintained at a sufficiently high temperature for a considerable period. It is thence concluded that the plaining period should never be curtailed. In all these reactions the bases are regarded as competing equally for the acids, and it is further assumed that all the materials of the batch enter completely into reaction.‡

If one type of base, R_2O or RO, be molecularly in excess, simple silicates will remain in the glass irrespective of the duration of plaining. This case may be differentiated from that arising from insufficient plaining, however, since it involves the formation of only one type of simple silicate ($R_2O,xSiO_2$ or $RO,xSiO_2$) whereas, in the other, both types necessarily occur. These simple silicates (the "semi-glass" of Zulkowski) are regarded as the prime cause of chemical instability.

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* Cf. Clarke, "The Constitution of the Natural Silicates," *U.S. Geol. Sur. Bull.*, 1914, No. **588**.

† Körner, *Sprechsaal*, 1915, **48**, 333.

‡ This involves the assumption, apparently open to question, that SiO_2 never occurs in simple solution in the more silicious glasses. Since, however, Zulkowski regards glasses which contain more than eight molecules of SiO_2 in the double silicate as prone to devitrification, which effect readily occurs also in those glasses in which free SiO_2 is regarded as being dissolved, the point does not appear to be of sufficient importance materially to affect the argument.

The simple silicates differ in their effect on the durability of the glass. Simple lead silicates, for example, are comparatively resistant to attack by water. A considerable molecular excess of PbO is, therefore, not incompatible with a fair degree of stability by certain tests. The proportion of silica, likewise, controls the effect of the "semi-glass" on the whole, the more silicious simple silicates being the less reactive and therefore the less conducive to instability.*

Zulkowski does not appear to have expressed a final opinion on the *rôle* of B_2O_3, Al_2O_3, or P_2O_5. These oxides have been variously regarded as replacing SiO_2 or as forming, with the bases present, simple compounds which dissolve in the glass. As is shown below, neither of these assumptions is adequate. The glasses discussed by Zulkowski, however, generally contained only small amounts of Al_2O_3, and no B_2O_3 or P_2O_5, so that his conclusions are, in the main, unaffected.

Appropriate heat treatment may cause devitrification by enabling simple silicates to crystallise † or by causing double silicates to revert to simple silicates which, supersaturating the glass, may separate in crystalline form. The devitrified material will thus be identical in composition with the original, in conformity with the results of Gröger and others.‡ The increased amount of simple silicates accounts for the increased solubility of the devitrified material (cf. Gröger, *loc. cit.*). The compounds present in the more silicious glasses may revert to less acid silicates, with separation of SiO_2 which may crystallise and so cause devitrification (cf. p. 70, note ‡).

Zulkowski's Calculation of Durability.

Zulkowski has employed a method of calculating the durability of a glass which may generally be expressed as below :—

Consider a glass of the following grouped molecular percentage composition :

$$\begin{array}{l}
\left.\begin{array}{ll} \mathrm{SiO_2} \ \ldots\ldots & a \\ \mathrm{R_2O_3} \ \ldots\ldots & b \end{array}\right\} \begin{array}{l} a + b \text{ molecules} \\ \text{of acids (Ac).} \end{array} \\
\begin{array}{ll} \mathrm{RO} \ \ \ \ldots\ldots & c \\ \mathrm{R_2O} \ \ \ldots\ldots & d \end{array}
\end{array}$$

and assume that $d > c$.

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* The conclusions of Kahlenberg and Lincoln (*J. Physical Chem.*, 1898, **2**, 77) and of Bogue (*J. Amer. Chem. Soc.*, 1920, **42**, 2575), from studies of the hydrolysis of silicates of sodium, are confirmatory.

† Cf. Donath and Indra, *Sprechsaal*, 1914, **44**, 160.

‡ Gröger, *Dingl. Poly. J.*, 1881, 297.

All the RO molecules, together with the same number of R_2O molecules, will combine with a proportion of the acidic oxides to form double silicates which may be formulated as

$$cR_2O,\ c\mathrm{RO},\ n\mathrm{Ac} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (1)$$

The residue of bases, $(d - c)$ molecules of R_2O, will combine with the residue of the acids to form simple silicates of the type

$$(d - c)\ \mathrm{R_2O},\ \ (a + b - n)\ \mathrm{Ac} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (2)$$

But the number of molecules of acidic oxides in each type of silicate must be in the same proportion to the total content of bases, whence

$$\frac{n}{2c} = \frac{a + b - n}{d - c} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (3)$$

whence

$$n = \frac{2c\,(a + b)}{c + d} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (4)$$

The silicates present in the glass in question may now be written

$$(\alpha)\ \text{double silicates}\ \ c\ \text{molecules}\ \mathrm{R_2O, RO}, \left(\frac{2(a + b)}{c + d}\right) \mathrm{Ac} \quad . \qquad (5)$$

$$(\beta)\ \text{simple silicates}\ \ (d - c)\ \text{molecules}\ \mathrm{R_2O}, \left(\frac{a + b}{c + d}\right) \mathrm{Ac} \quad . \qquad (6)$$

The necessary alterations in the above formulae when the RO bases are in excess $(c > d)$ will be obvious. The ratio of acidic to basic molecules, $a + b/c + d$, will rarely be integral. The double and simple silicates formulated above are therefore regarded as mixtures of homologous silicates, differing by unity in acidity-degree. It therefore follows that most glasses may be regarded as mutual solutions of four silicates, two double and two simple.

Zulkowski generally expressed his results in terms of molecules of simple silicates per 100 molecules of double silicates. Alternatively, the percentage weight of simple silicates was given. These appear to be no more advantageous than the much simpler quantity, $(c \sim d)$, which controls the proportion of simple silicates present, and which may conveniently be termed the "basic excess." In conjunction with the ratio of acidic to basic molecules, it is believed that this quantity may, in most cases, be employed as usefully as the results of the more laborious calculations in discussion of durability.

The following instances (Zulkowski, *loc. cit.*) may be quoted to show how the theory accords with the facts. The alkalinity determinations and analyses are by Mylius and Foerster.*

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* *Zeitsch. Instrumentenkunde*, 1891, **11**, 311.

TABLE I.

Percentage Composition of Glasses Examined by Zulkowski.

	1	2	3	4
SiO_2	75·4	78·8	79·1	76·5
$Al_2O_3+Fe_2O_3$	1·0	0·3	0·2	0·6
CaO	9·9	7·2	7·6	5·9
K_2O	4·4	3·6	6·7	6·6
Na_2O	9·3	10·1	6·4	10·4
Totals	100·0	100·0	100·0	100·0

TABLE II.

Durability Data for above Glasses.

	Per cent. by weight (Zulkowski's calculation).		Mols. of simple silicates per 100 mols. of double silicates.	Mg. of Na_2O liberated per sq. dcm. in	
No.	Double silicates.	Simple silicates.		3 days 20°.	1 hour 80°.
1	94·7	5·3	11	0·001	0·007
2	77·9	22·1	56	0·002	0·009
3	87·1	12·9	29	0·002	0·009
4	60·7	39·3	126	0·013	0·176

The best and worst of the glasses are correctly indicated, but No. 3, shown by calculation to be considerably superior to No. 2, is, by stability test, indistinguishable from it. This is ascribed to the fact that, in the case of No. 3 (a Bohemian glass), a considerable proportion of the simple silicate consists of potassium silicate. It is known that such a glass would more readily yield alkali to water than one containing Na_2O exclusively. It will therefore be seen that Zulkowski's theory gives a fair indication of the relative stability of these glasses, but that it cannot be employed to the exclusion of considerations based on qualitative composition.

Zulkowski's Theory in Relation to the Durability of certain Optical Glasses.

Twenty-seven optical glasses, covering all the common varieties, and selected at random from laboratory records, have been considered in this connection. Their liability to "filming" had been ascertained by the "dimming test," * and they had been graded in the following manner :

Unaffected or only very slightly affected .	Grade 1
Appreciably affected	Grade 2
Seriously affected	Grade 3

In intermediate cases, the sign + or — is added, indicating that the degree of attack is rather greater, or less, than the (mental) standard for the grade. The probable error in grading amounts to the difference between successive sub-grades, for example, 1 + and 2 —.

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* Elsden, Roberts, and Jones, this Journal, TRANS., 1919, 3, 52.

In the following tables the glasses are arranged according to the nature of the preponderating type of base and in order of diminishing durability.

TABLE III.

Grouped Molecular Compositions and Stability Data for Glasses Examined.

R_2O *Oxides Molecularly in Excess.*

		Grouped molecular composition (molecules per cent).					Percentage of simple silicates (Zulkowski's calculation).	
Ref. No.	Grade.	RO_2*.	R_2O_3.	RO.	R_2O.	Basic excess (R_2O—RO).	By weight.	By molecules.
100	1+	73·43	0·73	12·84	13·00	0·16	0·55	0·51
61	1+	74·46	0·69	12·08	12·77	0·69	3·02	2·90
18	1+	71·13	5·72	10·77	12·38	1·61	5·93	7·00
73	1+	78·21	0·42	9·73	11·63	1·90	7·86	9·06
69	1+	72·80	0·62	12·18	14·40	2·22	8·62	8·28
76	1+	77·62	0·82	9·25	12·32	3·07	12·22	14·14
64	1+	75·47	6·17	3·07	15·29	12·22	67·59	66·52
65	2—	78·78	0·08	10·31	10·38	0·07	2·08	2·48
2	2—	72·82	0·45	7·41	19·32	11·91	41·95	44·59
5	2	75·73	1·91	8·05	14·30	6·25	28·27	28·10
52	2	76·70	5·22	3·43	14·66	11·23	63·26	62·13
11	2+	73·56	0·11	12·01	14·32	2·31	7·39	8·76
48	2+	75·29	0·86	8·29	15·56	7·27	31·03	30·57
36	3	74·61	1·03	7·92	16·44	8·52	35·38	35·08

TABLE IV.

Grouped Molecular Compositions and Stability Data for Glasses Examined.

RO *Oxides Molecularly in Excess.*

		Grouped molecular composition (molecules per cent).					Percentage of simple silicates (Zulkowski's calculation).	
Ref. No.	Grade.	RO_2.†	R_2O_3.	RO.	R_2O.	Basic excess (RO—R_2O).	By weight.	By molecules.
20	1	68·39	1·00	20·09	10·52	9·57	36·41	31·34
63	1	57·54	6·68	24·54	11·24	13·30	39·90	37·12
56	1	61·95	9·55	24·14	4·36	19·78	70·71	69·18
54	1	51·01	26·23	22·25	0·50	21·75	66·16	62·89
59	1	53·01	13·97	32·42	0·60	31·82	71·80	68·56
70	1+	74·45	1·03	12·69	11·82	0·87	3·42	3·31
75	1+	70·52	0·60	15·94	12·94	3·00	11·38	10·35
53	1+	76·13	0·61	13·78	9·48	4·30	21·10	18·41
66	1+	77·94	0·15	13·62	8·29	5·33	16·60	24·21
67	1+	66·14	0·80	23·09	9·97	13·12	44·90	39·62
51	1+	54·25	13·28	31·83	0·64	31·19	69·77	66·63
62	2—	69·29	0·84	19·26	10·61	8·65	34·32	29·06
58	2—	67·33	0·67	22·38	9·61	12·77	45·15	39·96

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* The small amounts of Sb_2O_5 in these glasses have been included with the SiO_2.

† See note to Table III.

Comparison of the above data with the analytical results (not reproduced) shows no obvious relation between durability and the presence of particular oxides. There is no regular variation throughout these series between grades and basic excess or proportion of simple silicates. It will be seen, however, that a basic excess much above the average for glasses of any given degree of durability is always associated with a high proportion of oxides of the R_2O_3 group (compare Nos. 64 and 52, Table III, and Nos. 63—59 and 51, Table IV). If these glasses be excluded, it will be seen that a certain parallelism now appears between basic excess and grade. In a few cases (for example, Nos. 65 and 11) glasses have been found less durable than their composition would lead one to expect. This may be due to insufficient plaining during manufacture or to causes discussed below. It is noteworthy, however, that the reverse does not occur except in presence of much Al_2O_3 or B_2O_3, that is, that glasses of the "straight" crown or flint type in which one type of base greatly preponderates are not, in practice or theory, found to be durable.

Although the criteria of durability employed in connection with the dimming test are purely visual,* the high degree of correlation between the results of this test and the more purely chemical determinations of iodeosin values before and after weathering render it safe to conclude that the observations recorded above are not merely incidental to the method of testing, but are due to constitutional differences in the glasses examined.

The foregoing results are additional confirmation of the conclusion that Zulkowski's theory is valid only in respect of the simple crown and flint glasses. It is quite inadequate to account for the durability of glasses in which one type of base largely predominates and in which the content of Al_2O_3 or B_2O_3, or both, is considerable. Since many modern varieties of glass, including chemical and optical glasses, are of the latter type, it appeared necessary to endeavour to extend the original theory to include these cases also. In view of the complex nature of the term durability, however (*vide infra*), the validity of the criterion of durability which has been deduced has been tested by consideration of more purely chemical results already recorded in the literature.

Development of New Theory.

Practically every investigation into the durability of chemical glassware has led to the conclusions that B_2O_3 and Al_2O_3 confer stability, and that, in the case of the "straight" crown glasses,† a considerable content of alkaline oxides induces lack of resistance. As in the case of certain of the optical glasses described above, it has frequently been recorded that a high degree of durability is not incompatible with a content of R_2O_3 oxides numerically much below the basic excess. The conclusion appears to be indicated, therefore, that the stabilising effect of B_2O_3 and Al_2O_3 is considerably greater, molecule for molecule, than the contrary effect of basic oxides.

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* Full descriptions of the various effects produced, in relation to composition, are given by Elsden, Roberts, and Jones (*loc. cit.*).

† Containing no intentionally-added R_2O_3 oxides. See footnote, p. 84.

The *rôle* of aluminium in complex silicates, including glasses, has been the cause of much diversity of opinion, and the hypothesis that aluminosilicates exist has been adversely criticised by Clarke,* who concluded that "aluminium may so combine with silicic radicles as to form complex ions, but that it does so is quite unproved . . . the term 'aluminosilicate' may . . . be used as one of convenience, provided that we remember its limitations." There is, however, a considerable body of evidence in favour. Schwarz and Bausch † have recorded that interaction between SiO_2 and the cobaltammine complex occurs readily with the formation of new complexes. This observation they regard as considerably supporting the probability of the existence of complex silicates, aluminosilicates being instanced. Cobb has shown ‡ that, on heating to temperatures of 1000° or above the requisite materials for the formation of a substance having the composition $Na_2O,Al_2O_3,10SiO_2$, only about 3 per cent. of the product was soluble in HCl. In the case of the corresponding calcium compound, prepared at 1300°, less than 0·5 per cent. remained soluble in HCl. It is difficult to believe that any mixture of simple aluminates and silicates could exhibit such resistance to acid, and the conclusion appears to be warranted that aluminosilicate formation has actually occurred. Again, slight evidence was obtained, in the same investigation, that a product of the composition $Na_2O,CaO,Al_2O_3,10SiO_2$ was somewhat different in réactivity from a similar body containing no Al_2O_3. Further, the former body was produced at rather lower temperatures, as judged by experiments with Seger cones. The latter observations may, of course, be explained on the assumption that an aluminium silicate is produced which dissolves in, or dissolves, the other products of the reaction. They are, however, equally in accord with the existence of alumino-silicates. In an investigation of the rapid weathering of certain mirror-glasses, Selch concluded that the ratio of Al_2O_3 to alkalies was the factor controlling durability and that a high ratio was favourable.§ Appert has stated that 7 to 8 parts of Al_2O_3 per

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* *Loc. cit.*, p. 17.

† *Ber.*, 1921, **54**, [*B*], 802.

‡ *J. Soc. Chem. Ind.*, 1910, **29**, 69, etc.

§ *Sprechsaal*, 1912, **45**, 408.

100 parts of SiO_2 may be introduced into glasses, yielding products of good chemical durability.* Dimbleby, Hodkin, and Turner † have recorded experiments on the losses at red heat suffered by glasses of varying Al_2O_3-content which have been exposed to atmospheric moisture during grinding, and have found that the losses, which are approximately parallel to the extent of attack by water, diminished as the content of Al_2O_3 increased. The favourable effect of Al_2O_3 on durability has been extensively studied also by Cauwood, English, and Turner ‡ and by Cauwood and Turner.§

There is a considerable volume of evidence that B_2O_3 favourably affects the durability of glass. The frequency of its occurrence is indicative of its pronounced stabilising power. The insolubility and durability exhibited by borosilicate glasses, certain of which contain only negligible amounts of components other than the alkalis B_2O_3 and SiO_2, are conclusive evidence that they do not consist of simple borates and silicates in mutual solution, but that complexes are formed which exhibit towards corroding agents an inertness utterly foreign to the simple bodies. B_2O_3 and Al_2O_3, therefore, exert alike a stabilising influence. Because of the general similarity between them, it is assumed below that, as a first approximation at least, the same treatment may be applied to both.

By the theory now proposed, all the R_2O_3 oxides of a glass are regarded as forming complex silicates of the general type $3MO,R_2O_3,xSiO_2$. The remaining constituents are then assumed to form double and simple silicates, as in Zulkowski's original theory (*vide supra*). The details are shown below in the derivation of the reactivity coefficient. The durability of these complex silicates being taken as not inferior to that of the double silicates, the instability of a glass may still be ascribed to its content of simple silicates, which may readily be calculated as shown below.

In a number of instances, selected at random, modifications of the proposed theory were tested. Al_2O_3 and B_2O_3 were successively regarded as forming compounds of the type $2MO,R_2O_3,xSiO_2$, the remaining conditions being as described above. This treatment presented no advantages. It removed certain minor anomalies, but at the same time gave rise to discrepancies between calculated and observed reactivities considerably greater than any recorded below.

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* *Compt. rend.*, 1896, **122**, 672.

† This Journal, TRANS., 1921, **5**, 108.

‡ This Journal, TRANS., 1917, **1**, 153.

§ This Journal, TRANS., 1918, **2**, 219.

Modified Method of Calculating Durability.

The foregoing considerations lead to the following method of calculating the degree of durability of glasses of known composition.

Consider a glass of the molecular percentage composition

RO_2	a
R_2O_3	b
RO	c
R_2O	d

Case A.—When $c + d > 3b$, as is usual, it is assumed that all the R_2O_3 oxides will be combined according to the formula

$$3bMO,bR_2O_3,nSiO_2 \quad . \quad . \quad . \quad . \quad (7)$$

where M denotes R_2' or R''. There will be a residue of $(a - n)$ molecules RO_2 and of $(c + d - 3b)$ molecules of bases, from which double and simple silicates will be formed as before. Assuming the bases to be proportionally distributed among the silicates and complex silicates, the individual residues of RO and R_2O will be proportional to the amounts originally present, that is,

$$\text{Residue of RO bases} \quad . \quad . \quad \frac{c(c + d - 3b)}{(c + d)} \quad . \quad . \quad . \quad (8)$$

$$\text{Residue of } R_2O \text{ bases} \quad . \quad . \quad \frac{d(c + d - 3b)}{(c + d)} \quad . \quad . \quad . \quad (9)$$

As before, the basic excess is regarded as the source of instability. The bases combined as simple silicates will obviously be

$$\frac{c \backsim d}{c + d}(c + d - 3b) \quad . \quad . \quad . \quad . \quad (10)$$

The value of n in (7) may be taken, as in Zulkowski's theory, as proportional to the fraction of the bases contained in the complex silicate, that is,

$$\frac{n}{a} = \frac{3b}{c + d} \quad . \quad . \quad . \quad . \quad . \quad (11)$$

or

$$n = \frac{3ab}{c + d} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

The residue of RO_2 molecules, $a - n$, therefore becomes

$$\left(\frac{a}{c + d}\right)(c + d - 3b) \quad . \quad . \quad (13)$$

There are, in all, $(c + d - 3b)$ molecules of bases competing for these molecules of RO_2 (to form double and simple silicates), whence each molecule of base will combine with

$$\left(\frac{a}{c + d}\right)(c + d - 3b) \div (c + d - 3b) = \frac{a}{c + d} \text{ mols.} \quad . \quad (14)$$

Thus there will be

$\left(\frac{c \sim d}{c + d}\right)(c + d - 3b)$ molecules of simple silicates, of the general formula MO, $\left(\frac{a}{c + d}\right)RO_2$ . . . (15)

For the quantity $\left(\frac{c \backsim d}{c + d}\right)(c + d - 3b)$ the name "reactivity coefficient" is proposed.

Case B.—When the total content of bases is less than $3b$, complex silicates of higher R_2O_3 content, or of a lower degree of saturation, will be formed, and it is to be expected that, in general, such bodies should prove very stable. Excessive amounts of R_2O_3 (perhaps of the order of $c + d$) may be expected to produce unfavourable results. Devitrification would probably occur readily in such glasses, and since they are strongly acidic in nature, they may also be expected to exhibit considerable reactivity towards basic substances. In this connection the behaviour of Jena apparatus glass is of interest, Cauwood, English, and Turner having found it to be comparatively readily attacked by NaOH solution.* In the case of borosilicate glasses, an undue proportion of B_2O_3 would probably be conducive to ready hydration. This is believed to be the cause of the rapid disintegration of certain low-expansion glasses mentioned by Sullivan.†

Reactivity coefficients for these cases may be derived as above. Such formulas, however, are of limited application (some varieties of apparatus glass and certain types of optical glass). In such instances, stability may still be discussed by means of the formula derived above (No. 10), provided it be remembered that very large negative values probably indicate ease of hydration and, consequently, instability.

In endeavouring to estimate the degree of durability of glasses by means of the theory now proposed, certain obvious limitations, and a considerable number of qualifying circumstances, must be borne in mind. By means of the "reactivity coefficient" it is possible to arrive at an estimate of the proportion of simple silicates present in glass, but it is assumed that manufacturing conditions have been such that the formation of complex and double silicates has proceeded to the maximum degree. It therefore follows that the calculated degree of durability represents the maximum, all variations due to faulty thermal treatment in manufacture favouring reduced resistance.

The formula now proposed was derived solely from hypotheses of the molecular composition of double and complex silicates, which are believed to be the constituents of most glasses. Clearly, however, differences in stability between individual members of each group will affect the stability of the product. It is probable that the mode of combination of the bases will not be without effect on the durability of the glass. Thus, it is to be expected that differences in durability will exist between the alkali-double-silicates, the aluminosilicates, and the borosilicates of the various bases of the RO group. It appears probable that the basic constituents will, in most cases, influence the durability more than the acidic constituents. The complexity of the term "durability" indicates that no single expression can include every factor concerned, and the deduction of any precise measure of durability for any particular glass from its composition calls for fuller knowledge than is at present available. For this reason, therefore, the theory now proposed is regarded as of the nature of a second approximation in the computation of durability from composition.

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* This Journal, TRANS., 1917, 1, 153.

† *J. Soc. Chem. Ind.*, 1916, **35**, 513.

We are, however, not entirely ignorant of the other factors involved and in considering the results tabulated below the following experimental conclusions, which are confirmed by observations made in this laboratory, may be employed.

Particularly in the case of crown and flint glasses of the ordinary types, a high silica-content favours resistance to attack by acid. The influence of an unduly high SiO_2 content upon devitrification has already been mentioned. In the case of the crown and flint glasses, also, durability falls as the alkali content increases and it is generally found that glasses containing more than 15 per cent. of alkalies (by molecules) show diminished resistance. The content of bases, however, may be increased in presence of oxides of the R_2O_3 type.* While it is immaterial which alkali is present in the case of the most durable glasses,† it is found, in the case of the less resistant types, that potash glasses are the more readily attacked.‡ Slight increases in the alkali content, as has been demonstrated by Mylius and Foerster, may materially reduce durability. Zinc oxide, employed in many types of chemical ware, has been stated by Walker § to promote resistance, particularly when associated with B_2O_3. The borosilicate glasses, also, are regarded as generally more durable than the simple alkali–lime–silicates. The effect of large amounts of B_2O_3 on durability, however, is not wholly favourable. Cauwood, English, and Turner have pointed out that, whilst the best of the glasses they examined contained considerable amounts of this oxide, there appears to be a limit beyond which it is inadvisable to go. Glasses containing much B_2O_3 are susceptible to attack by acids, and for a glass of general durability the content of B_2O_3 should be limited. Contrary to Walker's conclusions, these workers find that a proportion of B_2O_3 may be replaced by alkalies and lime without impairing the durability. The amount of alkalies may be increased, in presence of Al_2O_3, without sacrifice of resistant qualities (Cauwood, English, and Turner), and this ingredient is of special value in increasing resistance to attack by Na_2CO_3. Alkaline solutions, caustic or carbonated, attack borosilicates, and glasses with high B_2O_3 content suffer extensively.*

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* Cauwood, English, and Turner, *loc. cit.*

† Mylius and Foerster, *loc. cit.*

‡ Mylius, *Zeitsch. Instrumentenkunde*, 1888, **8**, 267.

§ *J. Amer. Chem. Soc.*, 1905, **27**, 865.

Foerster has pointed out that it is impossible to secure a glass which will withstand all reagents, and Cauwood, English, and Turner have concurred. It therefore follows that no single durability test is adequate to determine the stability of a glass. The importance of varied tests is further emphasised by Foerster's observation that the effects of hot and cold water are not related in a simple manner and that differences in relative positions occasionally occur when a number of glasses are graded by stability tests with hot and cold water alone. It is generally found, in the following applications of the theory to published results, that agreement in order of grading is best when the tests are of a varied character, and that anomalies are most likely when the glasses have been graded on a narrow experimental basis.

Comparison of Theoretical and Experimental Conclusions.

In a paper on the composition of glasses suitable for chemical ware, Weber has recorded the composition and behaviour in use of eleven glasses employed in his laboratory.† It is noteworthy that they are all of the "crown" type, no borosilicates being present and the content of Al_2O_3 practically not exceeding 2 per cent. in any case.

TABLE V.

Grouped Molecular Composition of Glasses Examined by Weber.

	Oxides.				
Mark.	RO_2.	R_2O_3.	RO.	R_2O.	Total.
A	72·65	0·65	3·61	23·09	100·00
B	76·25	0·24	6·46	17·05	100·00
C	75·49	0·81	6·34	17·35	99·99
D	76·29	0·30	7·87	15·53	99·99
E	76·79	0·36	7·54	15·31	100·00
F	74·65	1·20	7·74	16·41	100·00
G	70·83	1·00	17·74	10·43	100·00
H	73·32	0·31	15·56	10·81	100·00
I	74·04	1·20	9·92	14·85	100·00
J	73·04	0·84	12·54	13·58	100·00
K	73·15	1·15	10·79	14·91	100·00

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* Foerster, *loc. cit.*

† *Zeitsch. angew. Chem.*, 1891, 662.

In the following table are given the various expressions which have been considered to control durability, together with Weber's remarks on the behaviour of the glasses in practice.

Table VI.

Durability Data for Glasses Examined by Weber.

Mark.	Behaviour of glass in practical tests.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{c+d}$.
A	Gave alkaline solution on boiling with water. Readily became rough and exfoliated on heating. Quite unsuitable for chemical apparatus	19·48	18·06	2·72
B	From a flask which, on standing for four weeks filled with water, became covered internally with a gelatinous deposit. The same effect was observed on refilling. Quite unsuitable for chemical apparatus	10·59	10·26	3·24
C	Like the above; also inferior . .	11·01	9·88	3·19
D	From Bohemian-glass flasks which were only slightly attacked on exposure to air or to HCl fumes. They lost about 0·012 gm. to boiling water in six hours.	7·66	7·37	3·26
E		7·77	7·40	3·36
F		8·67	7·21	3·09
G	French window glass of excellent quality; very resistant . .	7·31	6·53	2·51
H	Used in manufacture of lighthouse lenses; very resistant . .	4·75	4·58	2·78
I	"Hohl" glass; very durable . .	4·93	4·21	3·00
J	Similar to *I* in durability . .	1·04	0·94	2·76
K	Used by Weber; lost 0·008 gm. on six hours' boiling with water .	4·12	3·51	2·84

It will be seen that there is very close parallelism between the calculated and observed results, the durability of the glasses steadily improving as the basic excess and reactivity coefficients diminish. Coefficients of 10 units or more characterise the worst glasses, whilst the best have coefficients of 5 units or less. Glass *G* forms an exception to this generalisation, but its superior durability is obviously to be attributed to the fact that lime forms the basic excess and not, as in most instances, alkalies. It will be noted, also, that the new coefficients for *K* and *D* and *E* are approximately proportional to the losses in weight suffered by these glasses in the boiling-water test. Owing to their low content of R_2O_3 oxides, these glasses are graded almost equally well by Zulkowski's criterion. Comparison of *B* and *C*, *E* and *F*, and *H* and *I*, however, indicates that the proposed method of grading is slightly superior. No general relation is apparent between the acidity index, $a/(c+d)$, and the durability.

The following are the grouped molecular compositions of certain glasses examined by Foerster.* Full analytical results are given in the original.

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* *Loc. cit.*

TABLE VII.

Grouped Molecular Composition of Glasses Examined by Foerster.

No.	RO_2.	R_2O_3.	RO.	R_2O.	Total.
1	74·97	13·84	0·04	11·15	100·00
2	76·32	2·12	11·79	9·78	100·01
3	77·16	0·18	11·37	11·29	100·00
4	78·23	0·36	10·43	10·98	100·00
5	78·25	0·24	11·13	10·37	99·99
6	78·06	0·18	8·92	12·84	100·00
7	78·25	0·31	8·61	12·83	100·00
8	78·67	0·18	8·50	12·65	100·00
9	78·39	0·24	8·41	12·96	100·00
10	69·56	3·30	13·10	14·03	99·99
11	71·31	1·73	12·52	14·44	100·00
12	82·82	0·13	6·63	10·42	100·00
13	73·52	0·77	11·92	13·80	100·01
15	76·70	0·24	7·57	15·49	100·00
16	71·48	1·96	8·29	18·27	100·00
17	77·93	—	11·02	11·05	100·00

In order to compare the conclusions based on theory with the results of experiment, it was decided to allot to each glass an ordinal number representing its relative durability in each test and to compare the average values obtained on dividing the sum of these numbers by the number of tests on which they were based. Thus the best all-round glass would have the smallest number (that is, highest place) and the poorest, the largest. An alternative would be to express the results by each test in terms of the numerical effect for the least affected and to treat these values in the same manner. Such a method would, in general, lead to much greater differences throughout the series, but it is doubtful if the added labour of computation would lead to results of greater value than are yielded by the method adopted. Both systems, however, have the merit of being impersonal and in this way are free from the objections which may be urged against any method of comparison which entails "weighting" the experimental results. The method adopted is possibly not entirely free from objection, but it is believed that, over a number of tests, such as the various series of experimental results now in question, it is probably the fairest method of comparison. It has been employed in the construction of the following table.

TABLE VIII.

Relative Places of Glasses in Foerster's Tests.

No. of glass.	1	10	2	11	16	3	4	7
Total points . .	22	47	14	39	74	14	26	43
No. of tests . .	7	7	5	6	7	4	7	7
Average points .	3·1	6·7	2·8	6·5	10·6	3·5	3·7	6·1

No. of glass.	8	6	9	5	13	12	15	17
Total points . .	35	42	64	10	9	13	38	56
No. of tests . .	5	5	7	3	2	2	3	5
Average points .	7·0	8·4	9·1	3·3	4·5	6·5	12·7	11·2

The glasses examined by Foerster are of such diverse types that little is to be gained by comparing the data in the above table with the conclusions of theory, since not only will the effects of the varied constituents be concerned, but also those effects of constitution which, as has already been demonstrated, have a powerful bearing on the durability of glasses. The glasses have therefore been grouped according to the R_2O_3 oxides they contain. They are rearranged in Table VIII to facilitate this. When they are examined in this way, certain regularities appear which otherwise are largely masked.

1. Glasses containing more than 1 per cent. of Al_2O_3 by molecules: *

(*a*) Containing B_2O_3.

TABLE IX.

No.	Average points Table VIII.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{c+d}$.
1	3·1	11·11	−30·11	6·70
10	6·7	0·93	0·59	2·56

It will be seen that the glasses are correctly placed by the proposed theory, but that Zulkowski's original criterion fails.

(*b*) Containing no B_2O_3.

TABLE X.

No.	Average points Table VIII.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{c+d}$.
2	2·8	2·01	1·42	3·54
11	6·5	1·92	1·48	2·65
16	10·6	9·98	7·75	2·69

There is, in this case, considerably better agreement between Zulkowski's criterion and the experimental results, but the proposed method of calculating durability offers a slight advantage in placing Nos. 2 and 11 in the correct order.

2. Glasses containing less than 1 per cent. of Al_2O_3 by molecules:—

These glasses contain no B_2O_3 and the alumina present may probably with safety be regarded as adventitious (see footnote).

(*c*) Glasses subjected to over half the maximum number of tests:

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* The presence of impurities in the raw materials, notably in the sand employed, and solution of the substance of the pots or tanks in which the glasses are manufactured, almost invariably leads to the presence of small amounts of Al_2O_3 in the finished product. Unless this constituent has been added intentionally, however, the amount rarely exceeds 1 per cent. by molecules. Neglecting quantities less than this for the purpose of classification, these glasses may be divided into four main groups, namely:

(1*a*) Boro-alumino-silicates.	(2*a*) Borosilicates.
(1*b*) Alumino-silicates.	(2*b*) Silicates.

TABLE XI.

No.	Average points Table VIII.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{(c+d)}$.
3	3·5	0·08	0·08	3·41
4	3·7	0·55	0·52	3·65
7	6·1	4·22	4·04	3·65
8	7·0	4·15	4·04	3·72
6	8·4	3·92	3·82	3·59
9	9·1	4·55	4·40	3·67

Both criteria agree with the experimental results in designating Nos. 3 and 4 as the best, and No. 9 the worst, of these glasses. No. 6 is out of place, but the difference involved is so small that it may reasonably be concluded that both criteria are adequate.

(*d*) Glasses subjected to fewer than half the maximum number of tests :

TABLE XII.

No.	Average points Table VIII.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{(c+d)}$.
5	3·3	0·76	0·74	3·64
13	4·5	1·88	1·71	2·89
12	6·5	3·79	3·70	4·86
15	12·7	7·92	7·67	3·33

The agreement in order in the above table is exact. Since the experimental basis is possibly less satisfactory than in the above cases, this is not stressed.

(*e*) Lead glass :

The pronounced reactivity of this glass is difficult to explain. Both methods of calculation lead to the same low criterion, 0·03, indicating a fair degree of durability. This anomalous result, however, does not appear to indicate that the theory is at fault or that it is inapplicable to lead glasses. Such instability has not been observed in the case of a considerable number of potash–lead glasses examined here. It is also at variance with results obtained by Mylius and Foerster.* In their experiments, 20 gm. of the powdered glasses were boiled with water for five hours. The amounts dissolved were as under :

TABLE XIII.

Molecular composition of glass.	Mg. dissolved.
$Na_2O,CaO,6SiO_2$	7·4
$Na_2O,CaO,5SiO_2$	8·4
$K_2O,PbO,6SiO_2$	8·5

These results indicate that the reactivity of such a glass as No. 17 should be of the same order as that of similarly-constituted lime–soda glasses. While the glasses tested by Mylius and Foerster were in the form of sieved grains, regarding the surface equality of which some doubt may be entertained, the results can scarcely be entirely disregarded on this account. It would appear that the results in the case of No. 17 are possibly to be attributed to faulty manufacture of the glass, whereby insufficient time was allowed for plaining. The data for this glass are so far contrary to general experience that it seems justifiable to regard it as an abnormal specimen and to attach no importance to the discordance between theory and practice in this instance.

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* *Zeitsch. anorg. Chem.*, 1910, 67, 200.

A study of the durability of various American and Continental chemical glasses has been made by Walker.*

Details of the tests, with analytical results for the glasses, are given in the original. Walker found that flasks and beakers occasionally gave very different results. The data for the beakers, employed below, are regarded by him as the more trustworthy since they are free from the complication introduced by attack of the upper areas of flask walls not in contact with the liquid reagent. In Table XV the experimental results have been treated in the same manner as Foerster's, above, the order being altered for convenience.

TABLE XIV.

Grouped Molecular Composition of Glasses Examined by Walker.

No.	RO_2.	R_2O_3.	RO.	R_2O.	Total.
1	78·27	0·39	8·63	12·70	99·99
2	68·10	6·20 †	14·63	11·07	100·00
3	75·49	2·29	9·01	13·21	100·00
4	73·95	0·53	10·29	15·23	100·00
5	68·33	8·62	14·04	9·00	99·99
6	67·96	7·94	11·13	12·98	100·01
7	69·15	1·25	13·22	16·39	100·01
8	75·96	0·61	9·77	13·65	99·99
9	79·80	0·40	5·69	14·11	100·00
10	70·55	5·73	14·66	9·05	99·99
11	72·23	1·20	11·12	15·45	100·00

TABLE XV.

Relative Places of Glasses in Walker's Tests.

No. of glass.	2	5	6	7	11	3	10	1	4	8	9
Total points	14	17	20	30	2	31	16	20	16	19	23
No. of tests	4	4	4	4	1	4	4	4	4	4	4
Average points	3·5	4·2	5·0	7·5	2·0	7·8	4·0	5·0	4·0	4·8	5·8

These glasses may now be considered in the same manner as Foerster's (Tables IX—XII).

1. Glasses containing more than 1 per cent. of Al_2O_3 by molecules :

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* *Loc. cit.*

† Including 0·06 per cent. As_2O_5.

(*a*) Containing B_2O_3.

TABLE XVI.

No.	Average points Table XV.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{c+d}$.
2	3·5	3·56	0·98	2·65
5	4·2	5·04	−0·62	2·97
6	5·0	1·85	0·02	2·82

Excluding No. 11 as being insufficiently tested to establish its durability relatively to the others, it will be seen from Table XXIII that glasses 2, 5, and 6 are among the most stable of all tested. The reactivity coefficients express this fact well, but Zulkowski's criterion suggests poorer resistance and larger differences in relative durability than were found in practice.

(*b*) Containing no B_2O_3.

TABLE XVII.

No.	Average points Table XV.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{c+d}$.
7	7·5	3·17	2·77	2·34
11	2·0	4·33	3·74	2·72

The observations are insufficient for extended comparisons, but it will be noted that, as regards No. 7, the criterion of durability now proposed more nearly expresses the relative degree of stability found by experiment than that calculated on the original theory.

2. Glasses containing less than 1 per cent. of Al_2O_3 by molecules :

(*a*) Containing B_2O_3.

TABLE XVIII.

No.	Average points Table XV.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{c+d}$.
3	7·8	4·20	2·91	3·40
10	4·0	5·61	1·54	2·97

These glasses are correctly graded by the reactivity coefficients, and it is interesting to note that the ratios of their coefficients and of their average points are practically equal. Zulkowski's criterion, however, fails.

(*b*) Containing no B_2O_3.

TABLE XIX.

No.	Average points Table XV.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{c+d}$.
1	5·0	4·07	3·85	3·67
4	4·0	4·98	4·67	2·90
8	4·8	3·88	3·58	3·24
9	5·8	8·42	7·91	4·03

It will be observed that both criteria place the glasses in the same order, as has previously been observed in the case of glasses of the simple crown type (compare Tables VI and XI). They are in agreement with Walker's results in classing Nos. 1 and 8 as of practically equal durability and No. 9 as the least stable of the series. Glass No. 4, however, appears to be somewhat more stable than the criteria indicate. The difference is small and may be ascribed to the restricted range of tests employed.

The durability of several types of French and German chemical ware has been investigated by Nicolardot.* The compositions of the glasses, with descriptions of the tests, are given in the original. In Table XXI relative grades have been assigned to the glasses, as above, from the experimental results.

TABLE XX.

Grouped Molecular Compositions of Glasses Examined by Nicolardot.

Glass.	RO_2.	R_2O_3.	RO.	R_2O.	Total.‡
French *A*	73·13	0·38	12·42	14·04	99·97
French *B*	74·37	0·48	9·72	15·41 †	99·98
French *C*	71·83	5·00	11·26	11·90	99·99
Jena	67·20	7·81	16·93	8·05	99·99
Krasna	73·61	1·97	9·29	15·11	99·98
Kavalier	73·26	3·86	9·83	13·03	99·98

TABLE XXI.

Relative Places of Glasses by Nicolardot's Tests.

Glass.	French *C*.	Jena.	Krasna.	Kavalier.	French *A*.	French *B*.
Total points	20	18	51	48	31	28

These glasses may be considered in the same manner as Foerster's and Walker's.

1. Glasses containing more than 1 per cent. of Al_2O_3 by molecules :

No glasses of this type occur, the small amounts of Al_2O_3 which occur being, presumably, adventitious.

2. Glasses containing less than 1 per cent. of Al_2O_3 by molecules :

(*a*) Containing B_2O_3.

TABLE XXII.

Glass.	Total points Table XXI.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{c+d}$.
French *C*	20	0·64	0·23	3·10
Jena	18	8·88	0·69	2·70
Krasna	51	5·82	4·41	3·02
Kavalier	48	3·20	1·59	3·21

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* *Compt. rend.*, 1916, **163**, 355.

† Assuming this glass to contain 11·23 per cent. of Na_2O and not 31·23 per cent. as in the original (obviously a misprint).

‡ P_2O_5 has not been taken into account; the amounts present are too small to influence the calculations.

Zulkowski's criterion clearly fails in this case, since Jena glass, proved by these tests, as well as by many others, to be of high durability, is graded as the least resistant of all. The reactivity coefficient indicates that there is little to choose between Jena glass and the French glass *C*, and points to the Krasna glass as the least resistant of the series. The agreement between practice and the criterion of durability now advanced is substantially exact.

(*b*) Containing no B_2O_3.

TABLE XXIII.

Glass.	Total points Table XXI.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{c+d}$.
French *A*	31	1·62	1·55	2·76
French *B*	28	5·69	5·36	2·96

The slight superiority of glass *B* over glass *A* found experimentally is due mainly to its greater resistance to the action of boiling water in tests *A*—*C*. This is presumably to be in part attributed to the higher acidity-index of glass *B*, and also to the fact that it contains a proportion of K_2O in addition to Na_2O, whilst glass *A* contains the latter alkali alone. This case points to the necessity of relying on other data than theoretical criteria alone, and of qualifying, by reference to the composition of the glass, the inferences they afford regarding durability.

A valuable study of the durability of several types of chemical ware has recently been published by Cauwood, English, and Turner.* Particulars of the glasses and tests are given in the original. In the preparation of Table XXV the results of the first steaming test have not been considered, since the authors regard the losses in weight then found as less accurate than the remaining observations.

TABLE XXIV.

Grouped Molecular Compositions of Glasses Examined by Cauwood, English, and Turner.

Glass.	RO_2.	R_2O_3.	RO.	R_2O.	Total.
A	69·43	13·30	9·65	7·70	99·99
B	67·70	7·37	8·50	16·42	99·99
C	69·54	10·45	7·58	12·43	100·00
D	69·81	8·35	8·33	13·51	100·00
E	70·73	10·55	7·59	11·13	100·00
F	67·88	13·09	7·81	11·23	100·01
G	72·29	4·27	12·22	11·22	100·00
H	72·39	0·57	9·35	17·69	100·00
I	73·25	2·57	8·27	15·92	100·01
J	74·78	1·78	8·27	15·17	100·00

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* *Loc. cit.*

TABLE XXV.

Relative Places of Glasses by Tests.

Glass.	*D.*	*E.*	*C.*	*F.*	*A.*	*B.*	*G.*	*I.*	*J.*	*H.*
Total points .	153	157	176	195	237	250	140	269	293	324

These data may be considered in the same manner as Foerster's, Walker's, and Nicolardot's.

1. Glasses containing more than 1 per cent. of Al_2O_3 by molecules :

(*a*) Containing B_2O_3.

TABLE XXVI.

Glass.	Total points Table XXV.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{c+d}$.
D	153	5·18	−0·76	3·20
E	157	3·54	−2·45	3·78
C	176	4·85	−2·75	3·48
F	195	3·24	−3·63	3·56
A	237	1·95	−2·53	4·00
B	250	7·92	0·89	2·72

These glasses were found experimentally to be among the best of all tested, and the slight variations between the proposed criteria of durability are in satisfactory accordance with the experimental results. It will be observed that the values for this criterion are, in the main, negative, indicating the high stability of borosilicates of the general formulas 3MO, R_2O_3, $n$$SiO_2$, and 2*M*O, R_2O_3, $n$$SiO_2$, in agreement with previous conclusions. Zulkowski's criterion, however, does not agree with the experimental gradings, since it indicates a fair degree of instability in the case of glasses *B* and *D* at least, and would class the former with glasses *H*, *I*, and *J*, which were found to be insufficiently durable for chemical use.

(*b*) Containing no B_2O_3.

No glasses of this type occur.

2. Glasses containing less than 1 per cent. of Al_2O_3 by molecules :

(*a*) Containing B_2O_3.

TABLE XXVII.

Glass.	Total points Table XXV.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{c+d}$.
G	140	1·00	0·45	3·08
I	269	7·65	5·21	3·03
J	293	6·90	5·62	3·19

The glasses are correctly graded by the proposed criterion, which is superior to Zulkowski's. The relative values also, are in satisfactory agreement with the pronounced stability of glass *G* compared with the others, the reactivity coefficients of which indicate that they possess only low durability.

(*b*) Containing no B_2O_3.

TABLE XXVIII.

Glass.	Total points Table XXV.	$c \sim d$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.	$\frac{a}{c+d}$.
H	324	8·34	7·90	2·68

Both systems of calculation agree in characterising this glass as the poorest of the series, in accordance with experimental findings.

In a further paper from the same laboratory, an investigation of a series of crown glasses is described. The tests employed, with analysis of the glasses, are given in the original.*

TABLE XXIX.

Grouped Molecular Composition of Glasses Examined by Cauwood, Clarke, Muirhead, and Turner.

No.	RO_2.	R_2O_3.	RO.	R_2O.	Total.
1	74·71	0·21	0·23	24·86	100·01
2	74·77	0·18	1·64	23·42	100·01
3	74·49	0·19	2·82	22·50	100·00
4	74·59	0·22	4·13	21·06	100·00
5	74·26	0·30	5·10	20·34	100·00
6	73·43	0·58	7·07	18·92	100·00
7	74·53	0·33	8·40	16·75	100·01
8	75·04	0·22	9·17	15·57	100·00
9	74·79	0·31	10·46	14·44	100·00
10	74·31	0·34	11·56	13·78	99·99
11	74·26	0·30	12·89	12·54	99·99

It was found that as the content of CaO increased durability improved. The agreement between theory and experimental results is, as the following table demonstrates, extremely satisfactory. The practical constancy of the acidity index, $a/(c + d)$, the molecular proportion of R_2O_3 oxides, and the total content of bases, $c + d$, render it practically certain that the cause of this steady increase in durability lies in the progressive diminution in value of the term $c \backsim d$ in both criteria.

TABLE XXX.

Durability Criteria of Glasses Examined by Cauwood, Clarke, Muirhead, and Turner.

No.	$c+d$.	$c \sim d$.	$\frac{a}{c+d}$.	$\frac{(c \sim d)(c+d-3b)}{(c+d)}$.
1	25·09	24·63	2·98	24·01
2	25·06	21·78	2·98	21·31
3	25·32	19·68	2·94	19·24
4	25·19	16·93	2·96	16·34
5	25·44	15·24	2·92	14·58
6	25·99	11·85	2·83	11·06
7	25·15	8·35	2·96	8·02
8	24·74	6·40	3·03	6·23
9	24·90	3·98	3·00	3·88
10	25·34	2·22	2·93	2·13
11	25·43	0·35	2·92	0·34

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* Cauwood, Clarke, Muirhead, and Turner, this Journal, TRANS., 1919, 3, 227.

Conclusions.

It will be clear, from the very varied compositions and degrees of stability of the glasses studied, that the relation discussed in this paper is of a complex nature. It is, in addition, by no means simplified by the fact that the chemical durability of a glass cannot be regarded as an absolute quantity but must always be referred to the reagent employed. For example, Cauwood, English, and Turner found three glasses to be seriously attacked by water and alkali, whilst displaying considerable resistance towards boiling acid. The general durability of these glasses was low. Other glasses, proved by the complete series of tests to be generally highly resistant, were somewhat more severely attacked in the acid tests. Many similar instances, from these and other results, prove that this is no isolated anomaly but a general phenomenon. Despite such apparent contradictions, it is nevertheless possible to regard glasses, in a general way, as of high, medium, or low durability. Such a conclusion does not imply that their resistance to all corrosive agents will be similar or even of the same order. It would, indeed, not be difficult to prescribe for a glass of the highest general durability some chemical test in which it would display deficient resistance.

The calculated values, for which the terms "basic excess" (original theory) and "reactivity coefficient" (modified theory) are proposed, are intended as a measure of this general degree of durability whereby, from a knowledge of the composition of a glass, we may be able to form an opinion of its probable immunity from attack by reagents. These values, however, do not profess to predict behaviour towards particular reagents. In such a case the only adequate criterion is experiment. In the present state of our knowledge, indeed, more cannot be expected and, as has already been indicated, the possibility of the successful application of any theory depends on the perfection of manufacture of the material.

The causes leading to discrepancies between experimental and calculated results are probably numerous. Defective manufacturing processes, by unduly curtailing the "plaining" period, may have prevented the maximum formation of double and complex silicates from the simpler compounds initially produced, or may have left objectionable amounts of strain in the glass, due to imperfect annealing. Both causes would promote reactivity, and there is reason to regard the former as the more potent. Certain glasses, notably cast and moulded articles, are visibly inhomogeneous, "wave-marks" being evident. From the results of Cauwood, Clarke, Muirhead, and Turner (*loc. cit.*, p. 228) it appears that the boundary lines of such " waves " are peculiarly susceptible to attack by water. Mylius and Groschuff,* from certain irregularities in the extent of attack in hydration experiments, were led to suspect the homogeneity of tubing tested by them, and these observations have been confirmed in the examination of various types of commercial glasses in this laboratory. It is possible, also, that differences in reactivity may arise from the method of preparing the test-pieces. There is reason to believe that fire-polished glass (for example, blown apparatus) may be a trifle less resistant than machine-polished specimens (for example, finished optical parts) owing to the probability that a certain amount of stabilising will accrue from the exposure of the glass to water during the latter operation, whereby the reactive components of the surface layer may be partly removed. Experimental error, or too restricted experimental basis, may vitiate the general applicability of the practical tests. In alkalinity tests, for example, it is customary to express results in terms of milligrams of Na_2O liberated per square decimetre of surface tested. But in glasses containing K_2O and Na_2O the alkalinity so measured is certainly not wholly due to Na_2O. Further, if the glass contain CaO in addition, some may pass into solution and will again be reckoned as Na_2O. From the practical point of view, differentiation between the bases would often be extremely difficult, and, usually, is quite unnecessary. Where even only a series of different crown glasses is under consideration, therefore, it is clear that what is essentially an experimental error may conceivably vitiate inter-comparison. Where many different types of glass are in question (as in most of the series instanced above) the uncertainty due to this source is probably increased. The values calculated according to the theories now in question, likewise, are affected by errors in the analyses. The general expression for the magnitude of such errors is far from simple (owing to the transformation from parts by weight to percentages by molecules) but calculations indicate that it is improbable that analytical errors of the order regarded by Hillebrand † and others as allowable in rock analysis will affect the calculated values by more than about 0·1 unit.

The errors hitherto mentioned arise from what are essentially variations or faults in manipulation, but it is further likely that deficiencies in theory may also occur. The general agreement between the results of experiment and calculation appears to be strong confirmation of the validity of the theory and the assumptions on which it has been founded. It seems possible, however, that constituents may, on occasion, be encountered which display exceptional behaviour; for example, certain of the bases may fail to form some of the complex silicates premised, and so on. Whether such difficulties are to be expected in the case of glasses is not quite clear, although the possibility of such an occurrence is indicated by the fact that, in certain published results relating to syntheses, failures to prepare uniform series of silicates have been recorded. The fact that glasses are solutions would favour the formation of bodies possibly incapable of separate existence. Before the matter can be further advanced additional evidence is required along these and similar lines. The results submitted, however, are regarded as confirmatory of the existence, in glasses, of the double and simple silicates postulated by Zulkowski and the more complex bodies (aluminosilicates and borosilicates) suggested in the theory now advanced.

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* *Zeitsch. anorg. Chem.*, 1907, **55**, 101.

† " The Analysis of Silicate and Carbonate Rocks," *U.S. Geol. Sur. Bull.* **422**, 28.

Unlike Zulkowski's extension of Benrath's theory, which, as the foregoing results show, is applicable to the "straight" crown and flint glasses alone, the theory now proposed is capable of application to the borosilicates, aluminosilicates, and boroaluminosilicates. Whilst, as has been emphasised above, it is not possible always to apply the formula without qualifying its indications from considerations based on the composition of the glass in question, it nevertheless appears that, by means of the reactivity coefficient, a useful idea of the general durability of a glass may rapidly be obtained. What may be regarded as a chemical characteristic of a glass may thus be calculated with a degree of accuracy comparable with that pertaining to the calculation of its physical and mechanical constants, from its chemical composition.

Summary.

1. The theory advanced by Zulkowski has been reviewed and applied to twenty-seven optical glasses of known composition and durability.

2. To enable certain types of glasses to be included, for which the original theory has been shown to be inadequate, certain modifications in Zulkowski's theory are proposed. Both theories have been applied to the results of experimental studies of the durability of six series of glasses (sixty-five samples in all).

3. The use of the terms "basic excess" and "reactivity coefficient," as defined above, is suggested.

4. In the case of glasses of the "crown" and "flint" types (in which the molecular content of R_2O_3 oxides is below 1 per cent.) there is a fair measure of concordance between the experimental

gradings and the indications of Zulkowski's theory. The agreement is appreciably improved by the new theory.

5. Zulkowski's original theory fails to explain the durability of glasses containing any considerable proportion of Al_2O_3 and B_2O_3. The agreement between calculated and observed reactivities, by the proposed theory is as good as in the case of the simpler types.

6. It is difficult to trace any close or general connection between "acidity index" and durability.

7. In general, glasses of satisfactory resistance are found to have reactivity coefficients of under three units and the best commonly have values of two units or less. Negative values are generally associated with the most stable glasses, although very large negative values are probably undesirable. Glasses the coefficients of which exceed five units are unsuitable for chemical ware.

8. Certain possible sources of discrepancies between reactivity coefficients and experimental results are indicated and discussed.

I desire to thank Mr. G. H. Perry, O.B.E., Director of Chemical Inspection, for the interest he has taken in this work, and am indebted to the Director of Artillery, War Office, for permission to employ for this paper analytical and other results obtained in the work of the Directorate.

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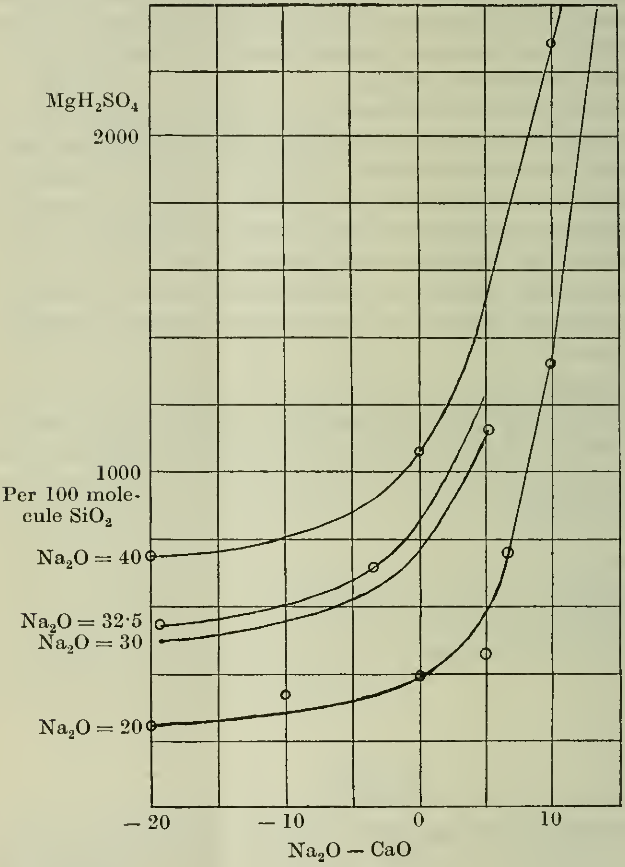
Royal Arsenal, Woolwich.

Discussion.

Dr. M. W. Travers (*communicated*) said he had recently had to study the relationship between solubility and composition in simple soda–lime glasses. He examined both the results obtained by Professor Turner and his colleagues and by Dr. Peddle; and as the latter covered the wider field he adopted them for reference and plotted them in the form shown in the accompanying diagram. The ordinates were the solubilities in terms of the quantity, in milligrams, of sulphuric acid required to neutralise the alkali set free in digesting 5 gm. of glass with 80 c.c. of water at 80° for one hour. The abscissæ were the values of the "basic excess" in molecular quantities per 100 molecules of silica. The result shows that for any particular value of the ratio Na_2O/SiO_2 the solubility increased with the value of the difference Na_2O-CaO. The increase was very slow until this value was zero, and then became rapid. According to Zulkowski's theory, the solubility should increase in both directions from the point at which the value of the difference Na_2O-CaO was zero, but this did not seem to be the case.



Professor Turner said that he would like to congratulate Mr. Baillie on the clearness of the exposition of his subject in the paper laid before the Society. The paper was quite a pleasure to read. In regard to the subject, it was one which the scientific worker, especially a worker who had any considerable knowledge of the subject of durability, was at times inclined to regard as incapable of being placed on a simple theoretical basis. Nevertheless, it was well that the attempt should be made from time to time. Both Zulkowski's theory and the extension of it suggested by Mr. Baillie depended essentially on what was to be regarded as the approximate chemical constitution of a glass in different circumstances. It had to be admitted in the first place that the results recorded by Zulkowski for lime and lead oxide-containing glasses were in very reasonable agreement with the theory, as also were those in the case of the alumina and boric oxide glasses calculated by Mr. Baillie's extension of the theory. He could not help but remark that most of the German attempts to derive a mathematical formula setting out the results of durable glasses were based on the common lime and lead oxide-containing glasses. What, however, was to be done from the point of view of the theory in the case of such a glass as Pyrex glass, which contained about 92 per cent. of acid oxides? He would also like to say that he was a little doubtful about the theory being found to be valid when the simple silicate in excess was no longer the alkaline silicate, but calcium or lead silicate. There were at present very few data which could help to solve this question, but such as did seemed to indicate that there was no considerable falling off in the solubility with excess of lime beyond the so-called "normal" composition. Moreover, it would be very interesting to know, remembering that calcium silicate was rather more readily attacked by water and other reagents than a number of other metallic ilicates of the same type, what the durability would be in the case of a glass containing excess of magnesium silicate. The only glass that he had acquaintance with containing slight excess of magnesium silicate was a little more durable than that corresponding with the so-called "normal" formula.

Mr. J. R. Clarke said that Mr. Baillie's extension of Zulkowski's theory of the constitution of glass was logical and interesting. The question arose, however, how far the theory was worth extending. It was not sufficient for a theory to account for the results of durability tests; it must also give a reasonable explanation of the other properties of glass, or, at any rate, it must not predict properties which examination showed did not exist.

The solution theory demanded that a series of glasses, such as the series $(2-x)$ Na_2O, xCaO, $6SiO_2$, should obey Gladstone and Dale's or Lorentz's law connecting the refractive index and the density. This definitely was not the case. Further, it afforded no explanation of the results obtained by Ambronn on the electrical conductivity of the simple soda–lime–silicate glasses. It was even questionable whether it was stisfactory when applied to explain the results of durability tests. It certainly succeeded in doing so in a vague way, but it seemed to him that a detailed explanation of the attack of various reagents, especially of the action of water and of alkalies on "excess alkali" glasses, was impossible on this theory.

A possible solution of the problem of the constitution of glass would appear to be derivable from the Lewis-Langmuir theory of the construction of matter. According to this theory, every mass of solid or liquid might be regarded as one large molecule. Work on crystal structure had shown that this was probable in the case of the crystals of the alkali halides, for example. In the case of sodium chloride, the chlorine atoms were situated symmetrically with respect to the sodium atoms so that it was impossible to say with which sodium atom a given chlorine atom corresponded. Vegard found a similar phenomenon in the case of the crystal zircon ($ZrSiO_4$). He concluded that this was a continuous lattice of alternate ZrO_2 and SiO_2 molecules, which were presumably held together by Langmuir's "residual valency." An analogous arrangement might apply in the case of crystalline sodium silicate, $Na_2Si_3O_7$. There were, however, many indications that glass (including amorphous $Na_2Si_3O_7$) was a very viscous liquid and not a solid. In the case of a liquid, the molecules were freer to move than in the case of a crystalline solid, so a regular spacial distribution of the molecules did not exist. Such a compound as $Na_2Si_3O_7$, or rather $Na_4Si_6O_{14}$, would, according to this theory, tend to split into ions Na^+, Na^+, Na^+, Na^+, Si_6^+, O_{14}^{----}. $Na_2O,CaO,6SiO_2$, would tend to become ionised so: Na^+, Na^+, Ca^{++}, $Si_6O_{14}^{----}$. Other more complex glasses might be similarly constructed. Thus, compliance with Gladstone and Dale's law would not be required; the electrolytic nature of the conductivity of glass was an inherent consequence of the theory; and Gray and Dobbie's deduction, namely, that the nearer a glass approached a definite chemical compound the lower its conductivity was rendered probable. A detailed consideration of the theory had not been attempted, but it was more likely to explain Ambronn's results than a solution theory. The attack of reagents on glass might be explained by consideration of the attractive forces by which the ions of the reagent were united and those by which the ions which form the complex glass molecule were held together. The great increase in the resistance to attack by reagents brought about by the addition of a small quantity of some substance such as ZnO would, on this theory, be due to the action of the substance in eliminating stray electrostatic and magnetic fields from the complex molecules, thus reducing the liability of the molecules to disintegrate.

It should be mentioned that R. B. Sosman had already evolved a theory of the structure of silicates on the Langmuir theory, but he had not yet seen his paper.

This suggestion of a theory to replace Zulkowski's did not diminish the value of one aspect of Mr. Baillie's work. By his system of points for durability tests and his extension of the solution theory he had produced a method by which one could tell approximately whether a glass was likely to weather well or badly, and this, no doubt, would be appreciated by manufacturers.

Mr. Baillie in reply (*communicated*) said the considerations and proposals advanced above were submitted as a second and closer approximation than had hitherto been available to the relation between reactivity and composition. The "reactivity coefficient" had been found by trial to explain and relate the durability and composition of the aluminosilicate and borosilicate glasses in addition to applying more successfully than the "basic excess" to the simpler crowns and flints. It was recognised, however, that this theory did not fully explain all the experimental data. It was difficult at present to decide how far this was due to qualitative differences in reactivity between the various types of compounds postulated (double silicates, borosilicates, etc.) and the specific effects of the various bases (for example, the ratio of K_2O/Na_2O; differences between molecularly identical compounds of Ca, Ba, Mg, Zn, Pb, etc.).

The possible application of the Lewis-Langmuir theory to the structural formulation of glasses was a very interesting speculation, and it was probably along such lines that certain matters, such as the different effects of the various RO oxides on their properties were to be explained. The present theory, nevertheless, appeared adequate to explain qualitatively and, in part, quantitatively much of the available data. Thus, it accounted for the pronounced durability of "Pyrex" and similar glasses. It admitted of the deduction, proved experimentally by Gray and Dobbie, that the electrical conductivity of glasses diminished as they approached definite chemical compositions (that is, single components according to the present theory), but that their actual conductivities were dependent on their composition. Applied to the results instanced by Mr. Clarke * it had been found that the graph of the reactivity coefficient against refractive index was, within the limit of experimental (analytical) error, substantially a straight line. It might be stated also that the Gladstone-Dale and Lorenz-Lorentz formulæ relating refractive index with composition applied very closely to these glasses, the variation in the values of the constants being about 1 per cent. in the former case and, in the latter, which also proved to give more concordant values, about 0·7 per cent.

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* This Journal, Trans., 1920, 4, 111.

An important question affecting the general theory now advanced was that of the effect of a basic excess of calcium oxide on the water-corrosion of glasses. It had already been emphasised that absolute parallelism between this property and general durability was rarely encountered, and that the theory did not profess to govern such specific instances. Since, however, water-corrosion was an important factor in determining general durability, and regular series of results had been cited, the matter was of considerable interest.

The results recorded by Dr. Peddle for glasses containing CaO, BaO, or PbO in combination with silica and one or both of the alkali oxides appeared to indicate that the water-corrosion of the glasses which contained RO oxides in excess of the proportion required by the normal formula was lower than that of glasses containing molecularly equivalent proportions of RO and R_2O oxides. Whether such a conclusion was valid appeared open to question. Dr. Peddle found it impossible to analyse the numerous glasses he prepared, and his conclusions regarding the relation between composition and the physical and chemical properties studied were based on calculated compositions. Many of the glasses were highly basic in character, and, as might be expected, pot attack was not infrequently encountered. From the present point of view, the most important result would be the introduction of Al_2O_3 into the glass and the more basic glasses (particularly, as Dr. Rosenhain has demonstrated, those rich in BaO), which were now in question, would be most affected. It was, therefore, impossible to say to what their reduced solubility should be attributed, and in view of the pronounced stabilising power of Al_2O_3 the data cited by Dr. Travers were regarded as insufficient to decide the point raised. It appeared to be necessary, as Professor Turner had pointed out, for this question to be specifically investigated. The results obtained would prove of considerable technical value also, in view of the suitability for certain purposes of glasses containing very high amounts of CaO (with, however, a considerable proportion of Al_2O_3 in addition).

The durability of glasses was the resultant of many factors, regarding many of which we possessed little knowledge, and it was not surprising that empiricism and contradictory data were so common. The purpose of the present paper was to demonstrate that the reactivities of the numerous glasses for which Zulkowski's theory had proved inadequate might be explained on a simple extension of the original hypothesis based on experimental results.

The validity of the conclusions advanced above was tested by application of the "reactivity coefficient" to all the durability data available at the moment of writing. He would submit that the degree of correlation which had been shown to obtain betwen theoretical and experimental results constituted the present theory a reasonable working hypothesis. If the "reactivity coefficient" proved of service by leading to the provision of glasses of superior durability, and if the general considerations and the results presented suggested lines of research which would add to our knowledge of this complex subject, a useful function would have been achieved.

VII.—*The Effect of Magnesia on the Resistance of Glass to Corroding Agents and a Comparison of the Durability of Lime and Magnesia Glasses.*

By Violet Dimbleby, B.Sc., Constance M. M. Muirhead, B.Sc., and W. E. S. Turner, D.Sc.

(*Read at the Sheffield Meeting, January* 18*th*, 1922.)

The increasing tendency to introduce magnesia as one of the alkaline-earth bases in glass batches makes it of particular interest to assemble as much detailed evidence as possible of its effect on glass. Glasses as widely apart as common bottle glass, electric bulbs, and chemical glassware have all in recent years been made with a considerable proportion of magnesia present, in company, in most cases, with a rather larger amount of lime. The question has been raised from time to time, especially concerning chemical glassware, as to whether lime or magnesia gives the better defence to corroding agents. An attempt is made in this paper to answer the question, and to set out results which may be of general importance besides.

Method of Test.

The corresponding lime-containing glasses were tested by suspending discs of the glass in the four boiling reagents used, namely, water, hydrochloric acid, sodium hydroxide, and sodium carbonate, the volume of the latter being maintained constant.* Practically the same procedure was adopted for the magnesia glasses with the exception of the water test. With this reagent also, discs were actually compared, but, unfortunately, very anomalous results were obtained for two glasses, although the remainder fell into regular order. It was thought that the discs, all of which were much alike, had, in the two cases mentioned, been unfortunately mixed, and in order to avoid the necessity of a further melting in order to obtain discs, a glass powder method was substituted, as a supply of glass for such a purpose was available in the form of rod.

For carrying out the powder test, the glasses were crushed and sieved, the portion between 20- and 30-mesh being selected for the test. Ten grams of the glass were introduced into a cylindrical bag made of platinum wire gauze, 90-mesh to the inch, rinsed with absolute alcohol to remove very small glass particles, quickly dried and re-weighed. The use of this bag made the handling of the glass quite easy, since it could be removed from the reagent, rinsed, dried, and weighed with convenience. Five hundred c.c. of water in a silica beaker were used and the bag was suspended in it to such a depth that the glass was covered. A period of one hour's boiling was given in all cases, but it must also be stated that whilst the glass in disc form was introduced into the cold reagent, the latter being brought to the boil and maintained boiling for an hour, the powder in the bag was placed direct into boiling water. When dry, the particles were examined by a lens to ascertain the effect of the water in producing etching.

Owing to the modification of method in the case of the water, it became necessary to carry out similar tests on the corresponding soda–lime–trisilicate glasses in order to obtain comparison. These two sets of glasses, namely, those containing lime and others containing magnesia, have been described fully in previous papers, and their compositions given.† They both follow the general trisilicate composition. The lime glasses range from $2Na_2O,6SiO_2$, to $Na_2O,CaO,6SiO_2$, each 0·1 molecule of Na_2O being replaced by 0·1 molecule of CaO successively, and $2Na_2O,6SiO_2$ to $0{\cdot}9Na_2O,1{\cdot}1MgO,6SiO_2$. The glasses in each series do not exactly correspond, but the differences are small as a rule. Both the percentage by weight and the molecular percentage of the lime or magnesia present are given in the table below.

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* This Journal, Trans., 1919, **3**, 228.

† This Journal, Trans., 1919, **3**, 222, 275.

The Action of Water.

The results of the tests, carried out on powdered glass as described above, are given below in the following table :—

Soda–Lime–Trisilicate Glasses.

	CaO content.				
Glass No.	Wt. per cent.	Mols. per cent.	Loss in wt. per 100 grm.	Per cent. Na_2O set free.	Remarks.
2	1·50	1·62	17·68	8·18	Much fine powder produced on corrosion.
3	2·61	2·81	2·78	2·56	Marked attack on the glass particles.
4	3·81	4·11	1·40	1·15	Visible evidence of attack but less than with No. 4.
5	4·50	4·84	0·60	0·44	Slight attack visible.
6	6·26	6·73	0·38	0·30	No visible evidence of attack.
7	7·45	8·00	0·27	0·14	No etching.
8	8·16	8·75	0·25	0·09	,, ,,
9	9·36	10·01	0·22	0·05	,, ,,
10	10·38	11·14	0·17	0·045	,, ,,
11	11·68	12·41	0·17	0·035	,, ,,

Soda–Magnesia–Trisilicate Glasses.

	MgO content.				
Glass No.	Wt. per cent.	Mols. per cent.	Loss in wt. per 100 grm.	Per cent. Na_2O set free.	Remarks.
24	1·10	1·66	2·62	2·01	Considerable attack but less than on corresponding lime glasses.
25	1·85	2·77	2·63	1·88	Considerable etching.
26	2·49	3·71	1·41	1·11	Distinct etching.
27	3·47	5·16	0·75	0·49	Slight etching.
28	4·20	6·23	0·35	0·25	No sign of attack.
329	5·09	7·48	0·39	0·13	,, ,,
330	6·10	8·95	0·15	0·075	,, ,,
331	6·87	10·02	0·10	0·05	,, ,,
332	7·46	11·01	0·11	0·04	,, ,,
389	8·45	12·21	0·12	0·034	,, ,,
390	9·30	12·38	0·07	0·02	,, ,,

The results indicate that for small amounts of lime or magnesia introduced into a glass of the type described, the magnesia is the more beneficial. The difference between the two glasses falls off with larger additions of lime or magnesia, but throughout the series the magnesia glass is superior to the lime glass. It may be remarked that the loss of weight due to the washing away by alcohol of fine glass powder before the experiment amounted to from 0·02 to 0·19 per cent. of the total weight, being most frequently about 0·07 per cent. Whilst this amount is small it is of great importance when dealing with the more durable glasses.

Action of Boiling Hydrochloric Acid.

Constant boiling hydrochloric acid containing 20·24 per cent. HCl was used. In this reagent, the discs were immersed, heated to boiling, and maintained boiling for six hours.

The extent of corrosion was measured by the loss in weight sustained per 100 sq. cm. of surface exposed.

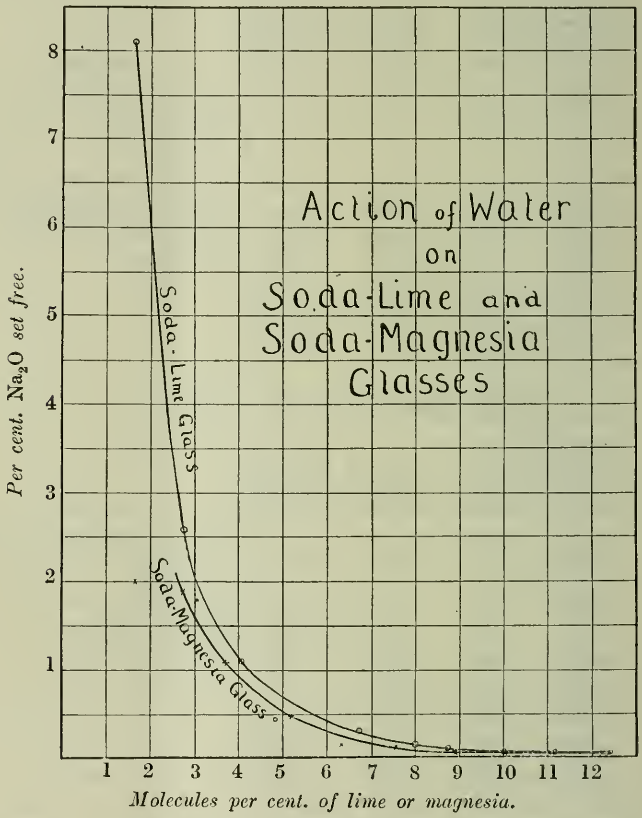

Fig. 1.

Losses in Weight in Milligrams per 100 *sq. cm.*

Glass No.	Lime glass.	Glass No.	Magnesia glass.
2	71·4	24	18·8
3	18·0	25	11·9
4	10·2	26	10·2
5	6·2	27	8·5
6	4·6	28	7·8
7	3·5	329	6·9
8	2·5	330	3·8
9	1·5	331	3·0
10	1·0	332	2·0
11	0·85	389	0·8
		390	0·2

It is clear that resistance to hydrochloric acid with change of composition varies more rapidly with the lime than with the magnesia glasses. When only a small amount of alkaline-earth base (lime or magnesia) is present, action is more pronounced on the lime glass, but as the amounts of these bases increase, the lime glass is a little better than the magnesia glass. It will be noted, however, that with large proportions of lime and magnesia, as in glasses 11 and 389, the differences are very small.

Over the whole range, therefore, one would draw the conclusion that there was no great difference between the effect of magnesia and of lime in so far as resistance to hydrochloric acid is concerned.

The Action of Boiling Caustic Soda.

The strength of the caustic soda solution was 2-*N* (or 80 gm. per 1000 c.c.). The period of boiling was three hours. Otherwise the test was similar to that for hydrochloric acid.

Losses in Weight in Milligrams per 100 *sq. cm.*

Glass No.	Lime glass.	Glass No.	Magnesia glass.
2	61·1	24	90·3
3	60·6	25	74·2
4	58·8	26	68·8
5	56·0	27	66·3
6	53·6	28	65·6
7	51·2	329	65·1
8	49·4	330	62·7
9	46·9	331	62·1
10	44·6	332	61·4
11	42·1	389	60·7
		390	57·5

It is quite clear that the lime glass is superior to the magnesia glass throughout the series in regard to corrosion by caustic soda solution. The loss in weight of the magnesia glass is from approximately 15 to 50 per cent. more than with the lime glass.

The Action of Sodium Carbonate Solution.

The strength of the solution was 2-*N* (or 106 gm. per 1000 c.c.) and the conditions of the test were precisely those with caustic soda.

Losses in Weight in Milligrams per 100 *sq. cm.*

Glass No.	Lime glass.	Glass No.	Magnesia glass.
2	234·0	24	284·2
3	83·8	25	149·7
4	45·5	26	122·1
5	35·5	27	115·0
6	32·3	28	84·2
7	30·3	329	75·0
8	27·8	330	67·1
9	26·7	331	64·7
10	26·0	332	63·8
11	25·1	389	63·0
		390	62·4

As with caustic soda solution, so also here the lime glass is superior to the corresponding magnesia glass. Indeed, except for the two glasses with least amount of lime and magnesia, the loss from the

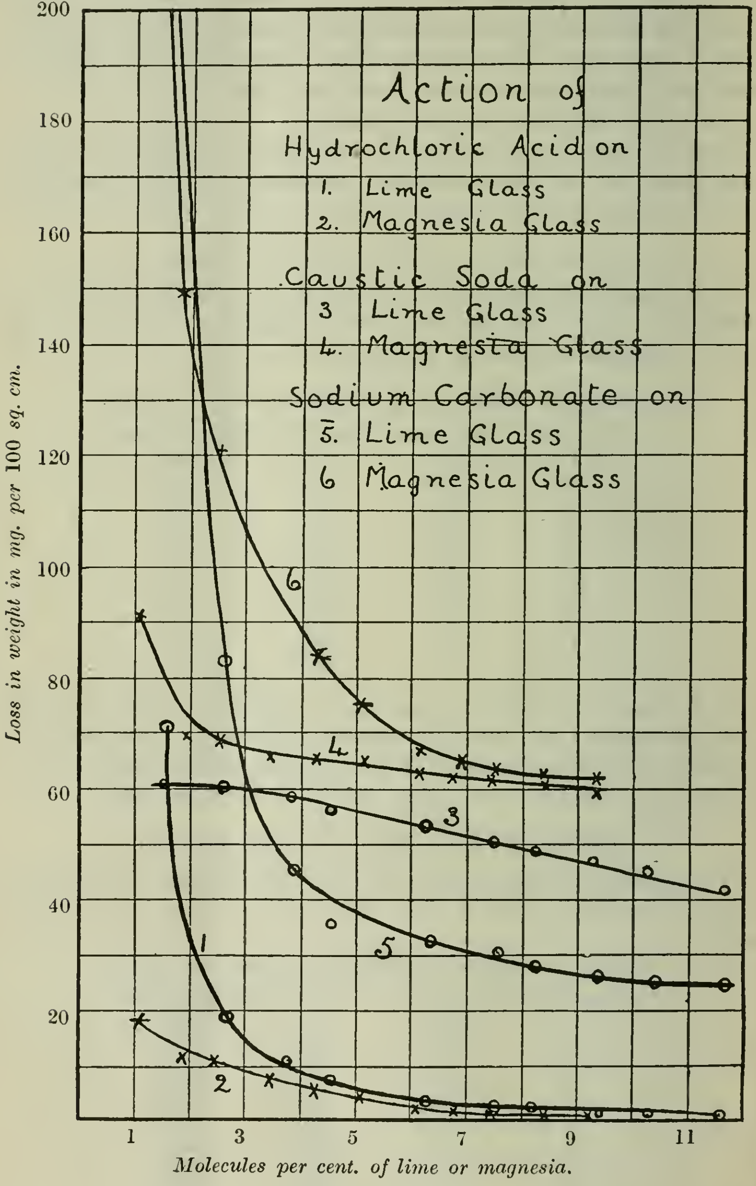

Fig. 2.

magnesia glass is from two and a half to three times that of the lime. Moreover, there is the interesting phenomenon with the magnesia glass that sodium carbonate solution is more corrosive than caustic soda solution. This was the case with the first two of the series of lime glasses, that is, up to 2·6 per cent. of lime, but with the magnesia glasses the greater corrosive action holds good over the whole range.

Curves are given, Figs. 1 and 2 setting out the relationship between molecular composition and degree of corrosion with both glasses.

Summary.

1. The chemical corrosive action of boiling water, hydrochloric acid, caustic soda, and sodium carbonate solutions have been determined on a series of soda–magnesia–trisilicate glasses, in which the percentage of magnesia by weight varied from 0 to 9·30. Comparison has also been made of these glasses with soda-lime glasses of corresponding molecular composition.

2. When the corroding agent was water, the magnesia glasses were found to be superior to the corresponding lime glasses over the whole range tested.

3. Substitution of a small amount of magnesia (up to about 3·5 molecules per cent.) for soda is more effective in improving durability towards hydrochloric acid than the use of a corresponding amount of lime; but for larger amounts of magnesia and lime, the glass containing the latter is slightly better.

4. Magnesia glasses are very distinctly less resistant to attack by either caustic soda or sodium carbonate solution than the corresponding lime glasses.

5. Over the whole range of the magnesia glasses tested, sodium carbonate solution is much more corrosive than caustic soda.

To sum up, magnesia glasses appear to possess a slight advantage over lime glasses in regard to corrosion by water; to show no advantage in the case of hydrochloric acid, and to be decidedly inferior when the corrosive agent is an alkaline solution.

Department of Glass Technology,
The University, Sheffield.

VIII.—*The British Glass Industry: its Development and its Outlook.*

PRESIDENTIAL ADDRESS.

Delivered at the ANNUAL MEETING, April 26th, 1922.

By W. E. S. TURNER, O.B.E., D.Sc., M.Sc., F.Inst.P.

INTRODUCTION.

THERE are, I suppose, few Societies of like character to our own which have not, during the past two years, felt something of the depression by which the industries they represent have been affected. The movement, enthusiasm, and hopefulness which so characterised the years of the war and early post-war period have in some measure given way under the continual fret and worry of trade difficulties and the failure of hopes once so fondly entertained. That the meetings of this Society have been so well maintained during the past year I take as a test of loyalty to the Presidency, a tribute to the amount of time, the attendance, and constant thought which Dr. Travers has exercised on your behalf, and finally to the fact that the Society has still continued to meet in its own particular line the great needs of the industry in which we all have a stake. Although we are no longer in the boom period and the office which you have asked me to fill is not without its difficulties, I can enter on it gladly after the loyalty shown to my predecessor; and although we do not wish to see him carried away either in a chariot of fire or on a pot carriage, yet for myself I may at least hope that a double portion of his keenness may descend on me.

In entering on a new year in the Society's life, and especially at the beginning of a new Presidency, there are some things which will bear restatement concerning the relationships of officers and members. It may also not be unwise if we set out a programme for the year, believing that even if we fail to carry it to completion, the efforts made will at least pave the way for our successors. For this reason I should like to say that the Council, with the assistance and support of every member, hopes, in addition to the normal work of the meetings of this Society, to be able to do something in a systematic way to provide standardised information for the industry. Already the Society has issued Provisional Specifications for certain refractory materials. It is the hope of the Council that these may be somewhat revised and re-issued; for scarcely any element in the glass factory is of more importance at the present time than the life of the furnace materials.

The Council also hopes to consider the possibility of issuing Specifications for some of the more important raw materials used in glass manufacture. It proposes to examine and to report on tests which may be applied to raw materials and also to glass itself.

There has also been a proposal approved by the Council for the preparation of a list of glass manufacturers and subsidiary industries in this country, and I am glad to say that, although some delay has taken place, that list is in the course of preparation. Members will be asked to give every assistance they can in its compilation in order that it may be complete. Above and beyond these things, there are still some larger plans for the work of the Society which are being evolved in the minds of your officers, but they will require further consideration by the Council before they can be put before you.

But if most of my references have involved the duties and activities of members of the Council, it does not mean that there is not a great part which each member of the Society may play. Thus, a pamphlet is to be prepared setting out the objects of the Society in order to gain membership. You will be invited to assist in increasing the membership of the Society until we can say that no firm in this country remains unrepresented in it and no person with an interest in glass technology shall remain ignorant of the benefits he might receive through the Society.

Some of the plans of the officers and some of the arrangements for the Society's meetings, however, may not quite fulfil all the ideas and expectations which members entertain of them. Let me say that in this matter none will be more grateful than the Council to receive help and suggestions from the general body of members, as indicating a living interest in all its efforts. The aim of the Council is to serve the Society; and one of its important functions to this end is undoubtedly to make as many members as possible articulate who are as yet dumb. There will therefore be provided a suggestion book which will appear at every meeting, and members are cordially invited to make entries in it of any suggestions or ideas that may be for the good of the Society; and I can promise that the Council will favourably and seriously consider them.

We want all members to realise that here in this Society all stand on an equal footing; that its meetings may serve to give some relief from the stress of modern industrial difficulties; so that the mere thought of being able to meet with their fellow-manufacturers on occasions when there are to be no discussions of prices, no conferences with the men over wages and hours of labour, but where all meet in an honest and common endeavour to improve and strengthen the fundamental basis of the industry, may prove so attractive as to conduce to still larger attendance and still greater freedom of speech.

Finally, there is little need to remind you of the importance of this particular year's work in that we hope to welcome our friends from the American Ceramic Society. Their interests are much the same as ours, not only in the development of a special industry but also in the larger ideals of present day civilisation; and I believe there are few members in whom the sentiment of kinship and common language will not be touched at the thought of the forthcoming meeting. You will be asked to welcome these visitors as friends. The Council has already been more than gratified at the expressions of goodwill made by our members in advance of the visit.

If the privilege of the President, however, on such an occasion as this, lay simply in setting out plans for the year and in exhortation of the members to continue in their loyalty to the Society, I can well believe that the Presidential Address would be expected to be of a somewhat brief character. I am therefore going now to depart from any further references either to myself, the officers, or yourselves severally, and endeavour to interest you in a matter which claims our united interests, namely, the British Glass Industry.

The Beginning of Glass-making in England.

How far back we may with preciseness date our industry cannot be stated. It is certain, however, from discoveries made in 1874 and again in recent years, that glass-making must have been carried on on the south side of the river at London during the time of the Roman occupation. Then follows a gap, and the story, scarcely begun, is broken. We reach the seventh century and learn that in A.D. 669 St. Wilfred introduced glass into the windows of a church to St. Peter at York and glazed the windows of the church of St. Paulin in the same city in A.D. 709, using the services probably of French workmen; whilst Bede tells us that when the monastery at Wearmouth was approaching completion, messengers were sent to Gaul to fetch makers of glass, who were at this time unknown in Britain. These foreign workmen, who probably arrived about A.D. 676, taught the English their handicraft, soon to be forgotten, it is feared, since Cuthbert, Abbot of Jarrow in 770, wrote to the Bishop of Mainz in Germany to engage him a glass-worker who could make glass vessels, for he and his monks were ignorant of the art.

Again a great silence follows, and the historian is left to conjecture. Glass-making in this country may have survived and been continuous through the centuries. Or, again, it may have broken out sporadically in various places, dying down and becoming extinct from time to time. We cannot tell. Further proof of its existence only comes to light in 1439, when the Countess of Warwick, in contracting with John Pruddhe, the glazier of Westminster, for glass for the Beauchamp Chapel at Warwick, stipulated that "no glass of England" but "glass from beyond the seas" was to be used.

Although there is some evidence that the making of stained glass was carried on in this country and reached a high standard early in the sixteenth century,* it is in the woods of Sussex and Surrey that we first hear of the activities of the glass-maker, in common with those of the worker in iron. In 1295, even, there were on the roll of jurors at Colchester † men whose names betray, or at least strongly suggest, the occupation of glass-making. Certainly in the sixteenth century there was a glasshouse at Chiddingfold in Surrey in 1557, and Kirdford, Wisborough Green, Loxwood, Petworth, Horsham, and Alfold are also mentioned as glass-making centres; and judging from the complaints of the Cinque Ports and other authorities regarding the destruction of the forests by glass-makers, the bands of roving glass-workers, moving their plant and appliances like the "fliegende Hütte" in the forests of Germany, must have become considerable in number.

But it was the continued leaven of foreign influence throughout the fifty years or more dating from 1549 that led to a real development of glass-making in Britain. The wealth and renown which Venice achieved through its glass manufactures in the fifteenth and sixteenth centuries were the envy of Europe, and the temptations to the Venetian workmen to ply their trade abroad, despite the heavy penalties they incurred for so doing, were sufficient to carry the more daring of them into Germany, the Low Countries, and finally into England. In 1549, eight glass-makers, quitting Murano, made their way first to Antwerp and then to London, whither they were attracted by the offers of Edward VI. It is probable they were set up in the hall of the Crutched Friars and for two years plied their art and taught English workers also. Seven of these workers left in 1551, but they proved the forerunners of several foreign bands whose influence was to be lasting in character.

If one is justly to apportion the credit for the industry's development during this period, most of it must go to those far-seeing men who were Queen Elizabeth's advisers and to the Sovereign herself. To these and the Englishmen of that vigorous period, ever ready for new enterprises at home or abroad, we must acknowledge our indebtedness. In the reign of Elizabeth were begun those monopolies or patents by which enterprising persons were induced to undertake new ventures on condition that, for a period at any rate, they enjoyed the sole right of trading in any particular commodity and thus of reaping whatever fruit they could for their enterprise. Success was not always their portion, and many of them incurred heavy losses, but the net result was that the glass industry, amongst others, steadily grew and became established. One of the first of these monopolies in glass-making was granted in 1575 to a Venetian, Verzelini, who settled in London somewhere about 1560 and became known as James Verselyne. The patent granted to him set out that he had "at his great cost erected a furnace in the City of London and had employed persons for making drinking glasses and had undertaken to teach and bring up in the said art and knowledge our natural subjects born within our realms of England and elsewhere, which art and knowledge when wrought hereafter by our subjects cannot but grow to the benefit of our common weal, for that great sums of money have gone forth from our said realms into the parts beyond the seas for that manner of ware."

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* See Albert Hartshorne's *Old English Glasses*, p. 160.

† Nesbit, *Glass* (London, Chapman & Hall, 1878) p. 121.

The granting of such a licence, which involved also a restriction or prohibition of imports, was vigorously opposed by the retail houses and the importers. They urged that it would bring ruin to fifty establishments engaged in the importation of glassware; would cause great loss to the shippers; a drop in revenue at the customs; not forgetting the devastation worked in our forests for the fuel consumed. It was, in fact, estimated that the consumption of billets of wood per glass house might be as much as 400,000 per annum.

The decision of the State, however, was not influenced by the petition, and from that time onwards a considerable competition resulted amongst different people, both Englishmen and foreigners, for the rights to patents and monopolies for glass-making. Indeed, at that day, not only in Venice, but also in France and in this country, the nobility thought it no mean thing either to have relations with glass manufacturers or for themselves to engage in its manufacture. We meet the names, for example, of Sir Jerome Bowes, Sir Percival Hart, Sir William Slingsby, Sir Edward Zouch, and Sir Robert Mansell, and finally, but not least, the Duke of Buckingham, who took over Mansell's * patent at the middle of the seventeenth century and carried on an important glassworks at Lambeth.

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* Both forms of spelling, namely, Mansell and Mansel, appear indiscriminately in contemporary documents, such as in those granting or renewing his patents.

I am quite sure that if the example set by Elizabethan times in recognising the glass industry were followed by present-day Governments, the Presidency of this Society would at least annually carry a knighthood and no honours list would be complete without some representative glass manufacturer being raised to the peerage.

Following Verselyne's patent, we find that George Longe in 1589 petitioned for a new patent and made the interesting observation that there were fifteen glasshouses then in England. In 1611, Sir William Slingsby obtained a patent for making glass with sea coal. The inventor of this new process, by which coal was employed as fuel, was said to be Thomas Percival, one of eight persons who, with Sir Robert Mansell, were granted a new patent on January 19th, 1614. In this patent, not only did Mansell acquire the sole rights of glass manufacture, but simultaneously the importation of foreign glassware was forbidden and the use of wood for fuel prohibited. It is to Mansell's efforts in no small degree that we owe the founding of a successful glass industry, and certainly the vigorous Tyneside industry must be attributed to him; for after unsuccessful attempts in London, in the Isle of Purbeck, Milford Haven, and Nottinghamshire, he finally succeeded at Newcastle-upon-Tyne. During the fifty years that followed his efforts had many rebuffs from those who were interested in foreign glassware or other enterprises, but, at any rate, a proclamation of 1664 * paid some tribute to his endeavours in that it prohibited importation of looking glasses and other plates, spectacle glasses, tubes, etc., on the ground that the Venetians were dumping goods in order to ruin a manufacture lately brought to perfection.

As already mentioned, the Duke of Buckingham appears to have taken over Mansell's London works, and John Evelyn in 1677 says: "We also saw the Duke of Buckingham's glass works where they make huge vases of metal as clear, pompous and thick as crystal; also looking glasses far larger and better than any that come from Venice."

The eight glass-makers from Murano were only the first of many foreign workmen. New makers came from the Low Countries and from Lorraine, and there was a steady stream of Venetians, who were successively engaged by Verselyne, by Mansell, and by the Duke of Buckingham. The band of noble glass-makers from Lorraine have exerted a lasting influence. They came, as Huguenots, largely to escape religious persecution, and appear to have arrived about 1575. Apparently they entered the forests of Surrey and Sussex and were heard of at Rye. Later a party of them crossed over to the Forest of Dean and still later, especially

* Mansell's death occurred prior to 1660.

when the use of wood fuel was prohibited, journeyed north, some of them staying in the Stourbridge neighbourhood,* where we learn that a child of the Tyzack family was baptised and entered in the registers of the church at Kingswinford in 1612. The three families particularly concerned were named, respectively, de Henzey, Tythery and Tyzack, the anglicised forms of De Hennezel, De Thiétry and Du Thisac. In 1618, one of Mansell's assistants at Newcastle was apparently one of these Lorrainers, named de Henzey. It is commonly believed that the industry in the Stourbridge neighbourhood grew up as the result of the Lorraine glass-makers. There is no definite information that glass-making was carried on in the Stourbridge area prior to the early years of the seventeenth century, although it is known that at a still earlier date the Stourbridge clay had been dug for making glasshouse pots, for a lease is extant of the year 1566 setting out the terms under which clay could be dug.

It was these two centres, namely, of Stourbridge and of Newcastle-upon-Tyne, that shared with London the rising fame of England as a glass-making centre. For, by the middle of the seventeenth century, the industry had become soundly rooted and before the close of that century had not only begun to establish a reputation, but had also developed definite national characteristics and made notable contributions in the extension of the art. The three contributions of special importance were the use of coal, the introduction of covered pots, and the discovery of the valuable qualities of lead glass.

The use of coal, which is claimed by Thomas Percival, undoubtedly made profound changes in the location of the industry and at once provided a basis for the successful establishment of the industry at Stourbridge and at Newcastle-upon-Tyne, and a reason for its disappearance from the woods of Surrey and Sussex.

It probably had a further consequence, namely, in adding difficulty for a time to the manufacture of glass of good quality, owing to the discoloration due to coal derived from the furnace; and it was doubtless to overcome such difficulty that covered pots were introduced.

In turn, the use of covered pots may have been one of the causes leading to the discovery of lead glass, since it is obvious the temperature inside the pot was reduced by closing it and melting therefore made more difficult. At any rate, this is the view generally entertained, although as to when lead glass was actually first made has been a matter of some dispute. Peligot placed the date as 1635. It is probable small amounts of lead oxide were gradually added to increase the fusibility. But it is quite definite that in 1662 a patent was granted to Thomas Tilson, who claims to have invented a "glass of lead."

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* Arthur A. Rollason, in a paper read to the North Staffordshire Field Club (see *Pottery Gazette*, 1920, **45**, 753), claims priority for Eccleshall in North Staffordshire over Stourbridge as the scene of the labours in the Midlands of the Lorraine and Normandy gentlemen glass-makers. The names of these glass-makers appear in the Eccleshall parish register as early as 1600–1604, whereas at Kingswinford the earliest record is 1612 and at Oldswinford 1615.

It was this glass of lead and its successive developments that brought name and fame to English glass-making, gradually ousting both the Venetian and the Bohemian glassware from favour. Thus, at the end of a century's working, England had achieved signal success in the production of artistic glass made from glass of a novel composition melted by coal as a new form of fuel, in pots of new design, namely, the covered type. Nor was it in flint glass alone that prosperity came; for by the middle of the same century, the seventeenth, London bottle-makers were exporting a considerable proportion of their manufactures to France, whilst in 1695 * the output of bottles in England was computed as 240,000 dozen.

The century that followed brought no decline. There are few landmarks to be noted, for it was a century of steady improvement. So much so that a French glass-maker, Bosc d'Antic, states that in 1760 English glass-makers sent four-fifths of their flint glass abroad ;† in fact, the whole of France, he declares, in 1760, was supplied with flint glass from this country despite its dearness and its occasional inferior colour. The high-water mark in English flint glass ware appears to have been reached in about 1780.

The Development of Glass-making in Different Centres.

I turn aside for a time from the main story to indicate something of the growth of the more important centres of the industry.‡

In historical importance comes London. It was the site of glasshouses under the Roman occupation. It was the centre of Verselyne's activities; many foreign glass-makers visited it between 1550 and 1600, whilst Mansell made his first efforts there. During the seventeenth and eighteenth centuries quite a number of well-

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* Buckley, *Old London Glass Houses*, privately printed, Stevens & Sons, Ltd., 1915.

† Hartshorne, *Old English Glasses*, p. 248.

‡ This address is intended to exhibit the main current of movement in the industry. I trust that some able person in each district, including Scotland and Ireland, to which no reference is made, will take up the subject and present the Society with authentic records of development in the separate districts.

known factories carried on their operations, but whereas in 1696 the number of glasshouses was twenty-four, by 1833 they had dwindled to three, and for another eighty years or so London remained comparatively insignificant as a glass-making centre. Time brings striking changes and once again London, in the last three or four years, has shown very marked development. Within its neighbourhood * there were, according to my list, in 1920–21 some sixty-three glass factories. There probably are a few more even, of a minor character. Many of these sixty-three are, indeed, small factories melting glass from cullet, a procedure quite traditional to the small London factories; for in his evidence before the Parliamentary Commission appointed in 1833 to consider the effect of the Excise Duties on the glass industry, Mr. Powell, of Bristol, directed attention to illicit small factories which evaded the duties imposed on the larger ones. There were, he stated, in London alone, quite thirty small manufacturers unknown to the Excise authorities, engaged in garrets and cellars, remelting in small furnaces the bottoms of tumblers and other broken glass and making the molten glass into cruets and castors, bird boxes and smelling bottles.

To trace the growth in London has proved a difficult matter, since the directories do not distinguish between actual manufacturers and agents of factories elsewhere in the country.

Newcastle-upon-Tyne and District.

The north-east coast, namely, Jarrow and Wearmouth, were the scenes of glass operations in the seventh and eighth centuries. In later days, it is claimed that as early as 1577 † glass bottles were produced in Newcastle by Thomas Liddell. Nothing is well authenticated, however, until Mansell established his factory on the Ouseburn in Newcastle in 1616.‡ By the end of the century, namely, in 1696,§ eleven glasshouses were in operation in the town and neighbourhood. In 1772,¶ there appear to have been in operation on the Tyne fifteen large glass works. In 1811, the total on the Tyne and Wear is given as thirty works, whilst in 1833 there were thirty-two, comprising some forty-one actual glasshouses. So important had glass manufacture on the Tyne become that in 1811 it was claimed, with what truth I cannot say, more glass was made there than in all the Empire of France.* Local directories have enabled me to compile a return of a fairly complete character from the beginning of the nineteenth century to the present date.

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* London and the home counties.

† See, for example, Nesbit, p. 128.

‡ G. B. Hodgson, *The Borough of South Shields from the Earliest Period to the Close of the Nineteenth Century*, pp. 357–370. 1903. (Reid & Co., Ltd., Newcastle-upon-Tyne.)

§ Houghton's *Letters*.

¶ John Brand, *The History and Antiquities of the Town and County of the Town of Newcastle-upon-Tyne.*, Vol. II, pp. 42–47. (London, B. White and Son and T. & I. Egerton, 1789.)

TABLE I.

Glass Factories on the Tyne, Wear and Tees.

<table>
<tr><th>Year.</th><th>Newcastle.</th><th>Gateshead.</th><th>South Shields.</th><th>Sunderland.</th><th>Middlesbro'.</th><th>Stockton.</th><th>Hartlepool.</th><th>Totals.</th></tr>
<tr><td>1696</td><td>11</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1810</td><td colspan="2">30</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1827</td><td>9</td><td>5</td><td>5</td><td>4</td><td></td><td></td><td></td><td>23</td></tr>
<tr><td>1833</td><td colspan="2">23</td><td>9</td><td>9</td><td></td><td></td><td></td><td>41†</td></tr>
<tr><td>1847</td><td>8</td><td>5</td><td>3</td><td>6</td><td></td><td>1</td><td></td><td>23</td></tr>
<tr><td>1851</td><td>10</td><td>6</td><td>3</td><td>9</td><td>1</td><td>1</td><td></td><td>30</td></tr>
<tr><td>1860</td><td>7</td><td>8</td><td>2</td><td>8</td><td></td><td></td><td></td><td>25</td></tr>
<tr><td>1870</td><td>8</td><td>9</td><td>2</td><td>13</td><td></td><td></td><td></td><td>32</td></tr>
<tr><td>1880</td><td>7</td><td>10</td><td>5</td><td>14</td><td></td><td></td><td></td><td>36</td></tr>
<tr><td>1885</td><td>5</td><td>7</td><td>4</td><td>14</td><td></td><td></td><td></td><td>30</td></tr>
<tr><td>1890</td><td>3</td><td>7</td><td>2</td><td>9</td><td></td><td></td><td>1</td><td>22</td></tr>
<tr><td>1895</td><td>3</td><td>8</td><td>2</td><td>10</td><td></td><td></td><td></td><td>23</td></tr>
<tr><td>1900</td><td>3</td><td>7</td><td>1</td><td>9</td><td></td><td></td><td></td><td>20</td></tr>
<tr><td>1905</td><td>3</td><td>6</td><td>1</td><td>6</td><td></td><td></td><td></td><td>16</td></tr>
<tr><td>1910</td><td>2</td><td>7</td><td>1</td><td>6</td><td></td><td></td><td></td><td>16</td></tr>
<tr><td>1915</td><td>2</td><td>8</td><td>0</td><td>6</td><td></td><td></td><td></td><td>16</td></tr>
<tr><td>1920</td><td>2</td><td>8</td><td>0</td><td>5</td><td></td><td>1</td><td></td><td>16</td></tr>
</table>

The industry of the Tyne and Wear was general in character, producing flint, bottle, and various forms of sheet glass. In 1811 seven works produced flint glass, eleven bottles, and twelve crown glass, the annual value of the last-named type being £320,000, two-fifths of the total for the country. Sheet glass had, indeed, been an important article of production from the days of Mansell's works. In 1640, Mansell complained to the Government that he had 1200 cases of window glass packed ready for shipping when the Scots descended on the works and his workmen fled. Shortly after 1680 small plates of glass were produced at Cookson's works. Through the eighteenth century and up to about 1833, crown glass was a very important industry, when it was gradually replaced by the French and German method of producing sheet. Six firms produced crown glass in 1838 but all were closed by 1863. Soon after 1845, Swinburne & Co., successors to Cookson & Cuthbert, at South Shields, introduced the manufacture of rolled cast plate glass, whilst in 1851 the firm was awarded a medal at the Great

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* *A Historical and Descriptive View of the County of Northumberland and of the Town and County of Newcastle-upon-Tyne*, Vol. I, pp. 208–212. (Newcastle, Mackenzie & Dent, 1811.)

† Excise Commissioners' Return. This states the number of glasshouses Probably some works were comprised of two or more glasshouses.

Exhibition for opaque plate glass, the first to be made in this country. In 1863, the South Shields works had a capacity for producing 1,240,000 sq. ft. per annum of plate glass, whilst at Sunderland the works of Messrs. Hartley & Co. produced rolled plate at the rate of 18,000 sq. ft. per week, or nearly 1,000,000 sq. ft. per annum. In 1886, the South Shields works covered seven acres of ground and employed 600 workpeople. In 1891, it ceased to exist, and to-day there remains but one sheet glass firm on the north-east coast, making now, not ordinary window or plate, but coloured sheet glass only. From 1880, other glass manufactures also declined. In 1862, a report to the British Association stated that there were no fewer than forty-seven bottle houses * in operation on the Tyne,† Wear, and Tees, producing per annum 4,230,000 dozen bottles. In 1920, the total number of glassworks of all types for the district was but sixteen.

Stourbridge and South Staffordshire.

Including Stourbridge, Wordsley, Brierley Hill, Dudley, Smethwick, and in more recent years also West Bromwich, Dudley Port and Tutbury.

TABLE II.

Glass Factories in Stourbridge Area (including South Staffordshire and Shropshire).

	1696.	1828.	1833.	1841.	1874.	1920.
Stourbridge and Wordsley	17	14	19	14		12
Brierley Hill						3
West Bromwich						1
Dudley and Dudley Port		6		6		2
Smethwick		2		2		1
Shropshire	1‡		2			0
Stafford			1			0
Tutbury						2
Totals	18 §	22	22	22	41	21

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* *The Industrial Resources of the District of the Three Northern Rivers, the Tyne, Wear and Tees*, being a report to the British Association meeting in Newcastle, 1863. (Longmans, Green & Co., London, 1864.) See pp. 197–204 and pp. 213 and 214. The number quoted, namely, forty-seven, may be of glasshouses and not separate firms or works. Cp. Table I.

† The industrial history of the N.E. coast is well told in the works referred to. See, also, the Official Local Guide for the Visit of the British Association to Newcastle-upon-Tyne, 1889, pp. 234 and 235 (Newcastle, Reid & Co., 1889).

‡ At Oaken Gate.

§ W. C. Aitken, in "Glass Manufacturers of Birmingham and Stourbridge," reprinted from the *Birmingham Journal*, Saturday, May 31st, 1851, says that in 1688 there were not fewer than twenty-eight factories in operation in the neighbourhood of Stourbridge, but in the reign of William III the number had decreased to seventeen.

The original industry in Stourbridge was clearly established by the three Huguenot families, the noble Lorraine glass-makers whose relatives also were active with Mansell at Newcastle. There is no authentic news of the industry before the early years of the seventeenth century, but the district was rich in resources of coal and of clay suitable for glasshouse pots. In 1696,* there were seventeen glasshouses, making the district second only to London in importance; in 1828, the number was twenty-two †; in 1830, Scott ‡ states that there were in operation fourteen glasshouses in Stourbridge, namely, one in Swinford (? Oldswinford), three in Amblecote, and ten in Kingswinford, whilst in 1833, nineteen are given in the Parliamentary return and with two neighbouring ones in Shropshire and one at Stafford the total remains at twenty-two. Eight years later, namely, in 1841, Stourbridge, Brierley Hill, Dudley, and Smethwick claimed twenty-two between them.§ Goodyear || states that in 1852 Stourbridge had twelve glass factories employing 1050 workers. The number had risen to forty-one in 1874, but in 1920 had declined to twenty-one. In the eighteenth century it made window glass as well as that with which the district has always been associated, namely, flint glass. Smethwick in the nineteenth century was an important centre for sheet and plate glass, Messrs. Chance Bros. now being the sole survivor in this branch of the industry. The works of this firm were established in 1814 by Mr. Shut as the British Crown Glass Works and passed into the hands of Messrs. R. L. Chance and J. Hartley about ten years later. In November, 1835, the firm paid as much as £17,150 excise duty on glass made. Between 1832 and 1838 the manufacture of Bohemian sheet glass was introduced and developed, foreign workmen being at first employed. Mr. James Chance also brought out the process of making patent plate by grinding and polishing sheet glass.¶ The same firm in the first half of the nineteenth century had already established a European reputation for optical glass and had become famous for lighthouse glass.

Besides the developments mentioned, several others are attributed to the district. Thus, George Ensall (a descendant of de Henzey) introduced the method of annealing in lehrs at his works at Tipton

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* Houghton, *loc. cit.*

† Pigot & Co.'s *Royal National and Commercial Dictionary.*

‡ William Scott, *Stourbridge and its Vicinity*, pub. by J. Heming, Stourbridge, 1832.

§ Pigot & Co.'s *Royal National and Commercial Dictionary.*

|| G. H. Goodyear, *Stourbridge, Old and New*, pub. by Mark & Moody, Ltd., Stourbridge, 1908.

¶ *The Birmingham and Midland Hardware District*, edited by S. Timmins, 1866, pub. by R. Hardwicke, London.

in 1780. In order also to acquire information, he disguised himself as a travelling fiddler, visiting many glassworks in Germany. His disguise was ultimately penetrated and he narrowly escaped with his life. The Red House Glass Works were erected at Wordsley to manufacture German broad glass as the result of Ensall's tour.*

A workman named James Chubsie at the works of Messrs. Grazebrook is stated to have shown how, at the beginning of the nineteenth century, to open out the tops of wine glasses, and in 1802, Charles Chubsie made the first open and shut moulds at the works of Messrs. Bradley, Ensall, & Holt.

Reference may also be made to the fact that Francis Egerton (died 1805), who brought the art of staining glass to a very high level, had his studio in Soho, Handsworth.†

Bristol.

Probably fourth in historical importance was Bristol. In 1761, there were fifteen factories making window glass, crown, flint, and bottle glass. By 1833, the number had been reduced to six, in 1853 to three, in 1874 to one, and in 1920, one. It is another town which has practically lost an old-established industry.

Lancashire.

Including Manchester and Salford, St. Helens, Warrington, Liverpool and Bolton.

Houghton, in his list of 1696, records two factories in Lancashire, one at Liverpool and the other at Warrington. The next record I have found is to the famous factory at Ravenhead, near St. Helens, set up by the British Plate Glass Manufactory in 1773.‡ It occupied thirty acres of land and in 1795 employed between 300 and 400 men. Grinding and polishing by a steam engine were started in 1789. About 1790 also, a window glass and small blown plate glass factory was set up. By 1816, Liverpool as a centre had considerably advanced, several factories being in operation.§ *Slater's Manufacturing Directory* for 1828 gives the names for the whole district as fifty-nine in number, but, unfortunately, it lumps together merchants and manufacturers, between whom it is not always possible to distinguish, especially those located in Liverpool and Manchester. Certainly the number fifty-four must be excessive, as the Excise return in 1833 makes the total nineteen. *Slater's Directory of the Northern Counties* for 1850–1 suggests a figure forty-seven, but the same difficulty as already mentioned occurs in sorting out the names at Manchester and Liverpool. A Parliamentary return, however, in 1874, gives the number for Lancashire as thirty-seven, indicating therefore considerable expansion and prosperity. In 1921, the number was only twenty, some factories being small.

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* W. C. Aitken, *loc. cit.*

† Fredk. W. Hackwood, *Some Records of Smethwick*, pub. Telephone Printing Co., Smethwick, 1896.

‡ *A Description of the Country from Thirty to Forty Miles round Manchester*, by J. Aikin, 1795.

§ *Commercial Directory for* 1816–17, by Wardle, and Pratt & Pigot, Manchester, 1816.

Table III.

Glass Factories in Lancashire.

	1696.	1828.	1833.	1850.	1874.	1921.
Manchester and Salford		(23) ?	5	(18) ?		12
Liverpool	1	(20) ?		(17) ?		1
Earlestown			9			1
St. Helens		10		9		6
Newton-le-Willows						1
Bolton		1				
Farnworth						1
Warrington	1		5	3		1
Burnley						1
(Bredbury) *						1
Total	2	(54)	19	(47)	37	25

Birmingham.

This city was somewhat late in its development of the industry. The first factory, namely, Hawker's, in Edgbaston St., was established in 1785,† Osler's dating back to 1807.‡ In 1828,§ the number had become eleven, besides numerous glass-cutting establishments, but the Excise return for 1833 only mentions five. However, a Parliamentary return for 1874 credits Warwickshire, which presumably means Birmingham, with forty-seven factories, the highest total in the list of counties and certainly the largest for any one city or town. The number now is but eighteen, a very significant diminution.

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* Near Stockport, Cheshire. It may be said to be within the sphere of influence of Lancashire.

† *The Making of Birmingham*, by R. K. Dent, 1894.

‡ "British Industries, III. Glass," in *Tinsley's Magazine*, August 1889, by Messrs. F. & C. Osler.

§ Pigot & Co.'s *Directory*, 1828.

Birmingham for a considerable period has been an important centre, not only for glass manufacture, but also for subsidiary processes carried out mainly by independent firms. Table IV gives some indication of these subsidiary trades, the data being extracted from contemporary (mainly Kelly's) directories.

Table IV.

Glass Industries in Birmingham.

	1828.	1833.	1841.	1854.	1884.	1896.	1904.	1921.
Glass manufacturers *								
,, (flint, etc.)	11	5	9	28	26	21	19	14
,, (bottle)			1		5	9	4	4
,, cutters			17	17	24		10	4
,, engravers				1	7	6		1
,, grinders					1			
,, embossers					7	4	4	3
,, benders					2	2	6	3
,, bevellers					4	7	9	10
,, gilders					4	3		
,, stainers and quickers				10	12			
,, enamellers				2				
,, toy makers				14				
,, blowers					4			2
Total	11	5	27	72	96	52	52	41

It may be mentioned that the first Siemens regenerative tank furnace in this country was that erected in 1856 at the works of Lloyd & Summerfield in Birmingham.

Yorkshire.

The big development of this district is comparatively recent, although, historically, the beginnings go far back. We have already noted the very early interest in glass for churches, and in this connection the stained glass in York Minster is perhaps the most famous old glass in the country. The earliest factory of which definite records exist was that at Bolsterstone,† near Sheffield, about 1650, although Hunter's *South Yorkshire* states that a glasshouse was erected and operated at Wentworth at some time between 1593 and 1641. In 1696, there were three ‡ factories;

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* One or two glass manufacturers appear also in the lists of subsidiary industries.

† Joseph Kenworthy, *Bolsterstone Glass House*, Deepcar, 1914; see also this Journal, Vol. 2, Trans, p. 1.

‡ Houghton's list gives the names of two factories only, namely, at Silkstone and at Ferrybridge. Bolsterstone glasshouse, however, was also in operation at this date.

for 1821 I have been able to trace six.[*] By 1833, there were ten, in 1850, twenty;[†] in 1874, twenty-nine; and in 1921, forty-five. The earliest factory made window glass and flint glass articles of elegant design. The flint glass trade was carried on in Hunslet and also later in Worsborough, near Barnsley, with great credit until well past the middle of the nineteenth century. Flint glass factories, now defunct, were operated in Attercliffe, Sheffield, by Melling, Carr & Co., by T. E. Mycock in 1862, and by William Langwell in 1872, the last flint glass factory, also in its earlier years at Attercliffe, being that of Langwell & Co., which disappears from record in White's *Directory* after 1905. The county is now almost entirely given over to bottle production, and is easily the most productive area for this type of glass.

TABLE V.

Glass Factories in Yorkshire.

	1696.	1821.	1833.	1850–51.	1874.	1904.	1920–21.
Barnsley and district	1	1	1	1		7	7
Castleford				4		3	5
Conisboro'				0		1	1
Dewsbury (Thornhill Lees)			1	1		3	3
Knottingley and Ferrybridge	1			0		3	4
Hull				1		1	1
Leeds		3	4	9		6	11
Wath, Mexboro' Swinton				1		4	4
Rotherham [‡]		2	2	2		2	1
Sheffield				0		3	2
Wakefield				0		1	1
York			2	1		2	2
Doncaster						1	2
Huddersfield							1
(Worksop) [§]							1
Total	3	6	10	20	29	37	46

The United Kingdom.

Unfortunately, statistics for the whole country are very hard to come by, but such as they are may be set out in the following table :—

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[*] *West Riding of Yorkshire Directory*, 1821.

[†] *Ibid.*

[‡] The firm now known as Messrs. Beatson, Clark & Co., Ltd., was in existence in 1750.

[§] Worksop is, of course, in Nottinghamshire, but is not far removed from the S. Yorkshire area. Mention may be made, also, of a flint glass factory at Whittington, near Chesterfield, which was operated between about 1730 and 1790 by a family named Dixon.

TABLE VI.

Glass Works and Glass Workers in the United Kingdom.

Year.	Factories				Total Workers.
	England.	Scotland.	Ireland.	Total.	
1696	88			(88)	
1785			9	(?)	
1833	106	10	10	126	
1861					15,046 *
1871	213	19	8	240	21,434 (20,284) *
1874	213	19	8	240	21,170
1881					23,647 † (21,630) *
1891					26,160 *
1895				230	—
1901					32,929 (30,081) *
1911					30,987 *
1921	189	19	5	213	

As showing how the industry has changed, it may be stated that in England in 1696 ‡ there were twenty-seven factories engaged in making flint and ordinary glass, fifteen in window glass, five in crown or plate, two in making looking glass plates, and thirty-nine in bottle-making. In 1847, in this country, there were as many as twenty-four window glass factories, but in 1867 only seven. In 1889, in the United Kingdom, there were four factories making sheet glass, four polished plate and seven rolled or rough plate, whilst the number of flint glass factories was forty-three.§ In 1920, there were but four factories (possibly five) making sheet or plate glass, whilst forty-seven were engaged in making flint glass, chemical and lighting glassware, gauge tubing, and optical glass.

A CENTURY OF COMPARATIVE PROSPERITY 1775–1875.

I have broken the main narrative in order to give some account of the growth and development in various areas, and I resume the thread of the direct story. There was little to relate of the major portion of the eighteenth century, development apparently being steady and continuous and reaching, in regard to the beauty of lead glass vessels, a culminating point about 1780. According to the title of this section, the century between 1775–1875 continued this prosperity; but I ought to emphasise that although progress was fairly continuous, glass manufacturers were engaged in a desperate struggle against strangulation by the Government. Up to 1845 and for a century preceding it, the glass industry, so one is tempted to declare, had been regarded by the State as a milch cow existing only for the sake of taxation and the support of numerous officials. If it still managed to show vigour and to do a very considerable export trade, it was due both to the levying of considerable import duties on foreign glass on the one hand, and to the granting of drawbacks or rebates of excise duty on glassware intended for exports on the other. But the amount of duty payable to the Excise was at times intolerable, crown glass at one time paying as much duty as 300 per cent. its actual value. The tax on windows also retarded the window glass industry, and was not removed until 1851, when it was replaced by the Inhabited House Duty. Some may remember old houses in which the windows originally designed were bricked in. As a child, I remember child friends who declared it was because there had been a funeral at the house, an explanation that held me in awe for many a day. The fact is, however, that taxation had been saved at the expense of light.

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* England and Wales only. An additional 10 per cent. will certainly cover the number employed in Scotland and Ireland.

† Stated in evidence before Tariff Commission, 1907, by Mr. J. J. Candlish.

‡ *Houghton's Letters.*

§ *Chambers' Encyclopædia*, 1895, Vol. V. p. 239

The Excise Duty on Glass.

The duty on glass was first imposed by statute in 1695, in the reign of William and Mary, and made perpetual by an Act in the following year.

The folly of heavy duties was soon brought home to the Government, and in the following session a further Bill had to be introduced reducing the rates of duty to one-half, the preamble to the Bill saying that "*it is found by experience that the said rates and duties upon glass and glass wares are too great, so that the said makers of those manufactures in this kingdom are thereby discouraged.*"

Even such reduction left the industry labouring under disadvantages; so much so that only one year later it was necessary to repeal the whole of the duties, it being found that they were not only difficult and costly to collect, but the diminished consumption of coal and the reduced employment resulting threatened soon to cause loss to revenue and industry far outweighing the duties in question.

Duties were again levied by an Act in 1746 (in the nineteenth year of George II.), corresponding duties being levied on glassware imported from abroad. The Act required the glass manufacturer to keep a record of all furnaces, pots, pot chambers, warehouses, etc., and to give due notice when pots were to be charged.

In the seventeenth year of George III. (1777), all former duties were repealed, merely to be replaced by others both on home manufacture and on imports. These duties were imposed on all the materials or metal or other preparations used in making various kinds of glass. Allowance was to be made to manufacturers for waste and imperfect materials.

Further regulations followed in the thirty-second year of George III. (1792), and applied particularly to the manufacture of flint glass.

In 1794 (34th George III.), heavy additional import duties were levied and various changes in regulations regarding the control of manufacture were made. These regulations, and others passed in the succeeding year (35th George III. c. 114), 1795, imposed severe penalties for evading duty varying in amount from £20–£500.

Further changes took place in Acts in 1807, 1809, 1811, 1814 and in following years (55th, 56th, 58th and 59th George III.).

During the reign of George IV. the manufacturer had to face another tax, for in 1826 (6th George IV. c. 81) every manufacturer had to take out an annual licence for every glasshouse, the annual licence costing £20. In the same year further changes occurred in the Excise regulations and the directions to manufacturers for carrying out their processes. The regulations were now made to apply for the first time to Ireland.

Other Acts followed in 1827 and 1828 (7th and 8th George IV. c. 53), 1830 (9th George IV. c. 48), and 1833 (3rd William IV. c. 102). Parliament must have had a busy time and manufacturers must have been official-ridden to such a degree that the recent war time visitations must be counted as but a light affliction.

Extracts from the Excise Regulations.

To what supervision the glass manufacturers were subjected may be gathered by reference to the Excise regulations issued during the reign of William IV.* The glassmaker was "to mark and number every workhouse, pot chamber, pot hole, lear, warehouse-room and other place so entered and made use of; and not to use any pot for preparing or making glass without first giving notice thereof to the proper officer. To take out and pay for a licence for each glasshouse, the duty on which is £20."

* Incidentally it is mentioned that the glass pots contain from 3–7 cwt., and they resemble garden pots for flowers, but those for flint glass have a globular cap or covering.

"Every annealing oven, arch or lear . . . for annealing flint glass to be made of a rectangular form with the sides and ends perpendicular and parallel to each other and the bottom thereof level and with only one mouth or entrance, with a sufficient iron grating affixed thereto and proper locks and keys and other necessary fastenings."

"Four hours' notice to be given to the officer of the intention to heat any annealing arch into which any pot for making glass shall be set. . . ."

"Twelve hours' notice to be given before beginning to fill or charge any pot for making glass . . . the hour at which it is intended to begin, the weight of materials to be used and species of glass to be made."

"Six hours' notice to be given in writing of intention to heat any oven, arch or lear into which any glass is intended to be put for annealing."

"In all glass chargeable by weight, the grating to the annealing arches to be closed and securely locked and sealed by the officers immediately after all the glass or wares have been deposited therein."

"In weighing glass the turn of the scale to be given in favour of the Crown."

Even glasshouses not in operation were watched like a cat watches a mouse; for "Glasshouses (in general) at which there are no fires but which houses are not wholly silent are surveyed twice a day and if wholly silent once only."

The Parliamentary Report of the Commissioners in 1835 admits that "A very slight examination of these complicated regulations will be sufficient to show in how great a degree they must necessarily interfere with the process of manufacture, and, in fact, take the general control and management out of the hands of the proprietor."

Glass Manufacturers' Protests.

It was no wonder that at length the glass manufacturers should rise up and protest; and indeed, they did most strongly in 1835, amongst the leaders being Mr. Cookson of South Shields and Mr. Apsley Pellatt of London, both well-known names. It was not until 1845, however, that the duties were repealed and manufacturers set at liberty.

Throughout the period in question the excise duty was continually changing and almost always in the direction of a big increase, thus continually adding to the cost of production. The following table sets out the rates of duty in operation at different times throughout the period :—

TABLE VII.

Rates of Duty on Glassware.

	Crown, Flint, Plate and White.		Plate.		Crown and German Sheet.		Broad.		Common Bottle.	
	per cwt.		per cwt.		per cwt.		per cwt.		per cwt.	
Year.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.
1770	9	4							2	0
1775	9	4							2	0
1780	18	8 (Plate)							3	7·2
	19	7·3 (Flint)					7	4·8		
1785	21	5½			15	8	7	10	3	11·4
1790	21	5½			16	1½	8	0½	4	0¼
1795	32	2½			24	2	8	0½	4	0¼
1800	32	2½			24	2	8	0½	4	0¼*
1805	32	8			24	6	8	2	4	1 *
	to				to		to			
	49	0			36	9	12	3		
1810					36	9	12	3	4	1 *
							to			
							15	0		
	Flint & Phial									
1815	98	0	98	0	73	6	30	0	8	2 *
1820	98	0	60	0	73	6	30	0	8	2 *
1825	84	0	60	0	73	6	30	0	8	2 *
1830	84	0	60	0	73	6	30	0	7	0
1834	78	7·6	60	0	73	6	30	0	7	0
1840	19	7·2 (?)	63	0 (?)	73	6			8	9
1844	19	7·2	63	0	73	6			8	9
1845	13	0 (?)	63	0	73	6			8	9

In 1812, the Excise duties were doubled as a war tax, and correspondingly heavy import duties were levied on foreign glassware entering the country.

What with the duties themselves and the stringent regulations concerning their collection, no wonder that research and experiment were either carried on at a serious loss or, what is true of much of the industry, not carried on at all. The composition of black bottles, for example, was by law restricted to certain raw materials, and as it was essential for a manufacturer to produce a certain percentage of glassware from every pot of metal, he had small scope for trials. M'Culloch, writing in 1833, says "Not only does the duty operate to prevent competition with countries abroad, but it operates also to prevent all improvement, because, to improve, experiments must be made, but a man with 125 per cent. duty over his head is not very likely to make experiments. This argument applies especially to colours."

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* Rate for Ireland 1s. 3¼d.

Mr. Powell, of Bristol, also in his evidence to the Commissioners in 1833–34, states that experiment is prevented because a manufacturer must produce at least 40 per cent. out of the metal in the pot to meet the excise duty or must pay duty on the deficiency. He also illustrates the irritating delays caused by the necessity for supervision by the experience of one factory which produced 6,000 ink bottles per day and not one of them could leave the premises until they had been stamped officially with the symbol EX.

A French glass engineer, H. Fontenay, writing in 1877, states that the English productions up to 1850 had not quite reached the level of quality of the continental glass manufacturers, and the reason generally attributed to this somewhat low level was the influence of the Excise duty throughout a long period.

When the Excise duty was removed, no fewer than 450 civil servants, comprised of 8 collectors, 10 clerks, 13 supervisors, 339 officers, 8 assistants, and 32 others, and 42 engaged at the headquarters of administration, the wharf offices, etc., lost their jobs with a saving in salaries, etc., of £52,636 per annum. No tears need be shed about this loss, since the report suggested that these civil servants would probably be absorbed in some other department.

Consequences of the Repeal of Excise Duty.

The immediate effect of the repeal of the duties was to give a great impetus to the industry. This information is given in a series of letters written in 1846 by manufacturers.

For crown and plate and sheet the demand far exceeded the supply and led to the formation of new companies with capital of £200,000. In the case of window glass the amount made in 1845 went up 50 per cent., leading to a shortage of workmen. The consequence was to attract Belgian and French workmen, and it became necessary in Belgium to raise the glassworkers' wages to prevent them being tempted to England. Wages as high as £4 to £8 weekly are said to have been made by English workers, and the men endeavoured to enforce onerous stipulations.

Another manufacturer writes : " We have exchanged the Excise for a much severer taskmaster, *videlicet*, our own men." Wages between 1844 and 1846 (February) had already risen 30 per cent.

Of the flint glass industry, another manufacturer writes that it has received considerable impetus. There had been a 20 per cent. increase in quantity and also an improvement in quality.

There was one other striking result of the removal both of Excise duties and of import duties on glass, namely, that the demand in this country became so great that exportation fell very greatly in 1845, whilst the value of the imports was very much increased. This, however, was but a temporary effect.

Glass Production from 1770 *to* 1845.

Although from the point of view of the industry the Excise duty had been nothing more than a stumbling-block, the historian, at any rate, is quite glad of the fact that precise records had to be kept. They help us of a later date to realise something of the growth of the industry. We are enabled, for example, to study the yearly production of different types of glass in the United Kingdom during this period of seventy-five years.

The following table provides a continuous survey from 1770 to 1845 :—

TABLE VIII.

Production of Different Types of Glass on which Excise Duty was paid, 1770 *to* 1845.*

	England.		Scotland.		Ireland.		Total.	
	Duty Paid.	Weight.	Duty Paid.	Weight.	Duty Paid.	Weight.	Duty Paid.	Weight.
Year.	£.	cwt.	£.	cwt.	£.	cwt.	£.	cwt.
1770	85,260	385,010	2,594	25,940			87,854	410,950
1775	89,095	398,370	3,186	31,860			92,281	430,230
1780	109,212	254,630	7,020	35,180			126,232	289,810
1785	141,064	320,660	9,002	34,590			150,066	355,150
1790	187,492	410,420	16,633	58,300			204,125	468,720
1795	216,897	373,370	25,148	84,890			242,045	458,260
1800	253,415	388,310	25,159	86,340	1,833	28,850	280,407	503,500
1805	343,515	445,970	51,983	96,920	1,439	22,650	396,937	565,540
1810	443,525	512,490	75,823	111,040	896	14,100	520,244	637,630
1815	735,569	424,230	115,817	94,430	388	6,110	851,774	524,770
1820	654,529	366,230	127,595	86,950	415	6,530	782,539	459,710
1825	907,411	537,590	163,097	96,230	263	7,160	1,070,771	640,980
1830	618,067	415,750	87,155	68,890	5,343	18,830	710,565	503,470
1834	868,257	494,440	36,824	55,940	4,055	15,370	909,136	565,750
1840	792,853	595,260	64,200	114,160	11,149	18,580	868,202	728,000
1844	722,007	479,700	51,246	84,720	6,541	10,880	779,794	573,300
1845	780,606	591,420	58,284	106,350	6,371	13,950	845,261	761,720

Despite the crushing effect of the duty, there was quite a definite increase in production throughout the period, the respective types of manufacture contributing as follows :—

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* The weight has been calculated from the total duty paid and the rates of duty as stated in Table VII.

TABLE IX.

Production of Glassware in the United Kingdom.

Year.	Crown, Flint, Plate and White. cwt.	Plate. cwt.	Crown and German Sheet. cwt.	Broad. cwt.	Common Bottle. cwt.
1770	127,410				283,540
1775	134,220				296,010
1780	41,900		48,680	24,040	175,190
1785	41,100		71,420	16,900	225,830
1790	52,010		99,460	21,600	295,650
1795	56,150		65,870	22,090	314,150
1800	71,200		82,070	20,430	329,800
1805	70,980		112,760	14,650	367,150
1810	88,300		115,690	10,030	423,610
	Flint and Phial.				
1815	56,630	9,710	101,750	8,450	348,230
1820	52,880	10,000	98,870	8,030	289,930
1825	64,570	15,640	160,710	8,380	391,680
1830	47,980	13,300	96,560	4,840	340,790
1834	59,330	18,930	136,710	6,770	344,010
1840	100,160	27,060	130,200	8,510	462,070
1844	84,980	20,920	131,380		336,020
1845	94,770	29,770	135,900		451,280

In the Great Exhibition of 1851 British glass manufacturers stood high in the competition list. British glass won the first prize in the flint or lead glass section, and especially noteworthy were the displays of crown glass, polished plate, and optical glass. The great advantage which certain Continental countries possess in regard to their sand supplies appears to have been brought out, for Shaw,* lecturing at the Royal Society of Arts on the lessons of the Great Exhibition, states that in regard to plate glass, "we generally excel our Continental neighbours in those respects in which excellency is dependent on manufacturing facilities and manipulatory skill, whilst we are frequently inferior to them in purity of colour."

From that time onward to the close of the period under review there were increasing advances and prosperity, although the manufacturers complained that the workmen were at times adopting an attitude which in the long run was not to their own interests. The year 1874 appears to mark the high-water mark of the prosperity of the industry.

FORTY YEARS OF STRUGGLE, 1874 TO 1914.

I have stated that the year 1874 appears to have marked the culminating point in the progress and prosperity of the British glass industry. In that year we stood well in the list of glass-producing countries, being approximately third in importance (second in number of factories and fourth in regard to workers.) The value of output is not known.

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* G. Shaw, Lecture on Glass, Royal Society of Arts, 1852.

TABLE X.

Glass Factories and Glass Workers in the Most Important Glass Producing Countries.

	1874.*		1895.†	
	Factories.	Workers.	Factories.	Workers.
Germany	348	(?)	312	71,300
Austria	203	60,000	200	50,000
United Kingdom	240	21,170	230	22,000
France	175	22,830	200	50,000
U.S.A.	213	17,243	294	50,000
Russia	165	(?)	200	20,000
Belgium	68	12,000	70	22,000
Italy	46	2,000	50	10,000
Sweden	28	(?)	30	2,000
Holland	23	1,100	35	3,000
Spain	23	(?)	8	700
Denmark	4	700	6	400

This date of 1874 is referred to by glass bottle workers as the best year; whilst it agrees with a note sent to me by Mr. Duncan Webb stating that after 1875 the flint glass industry began to suffer decline, whilst Mr. Harry Powell in 1917 informed me that it was shortly after the Franco-Prussian War when German soda glass began to enter this country in considerable amount to the disadvantage of British lead glass.

Various reasons have been assigned for this check to the British glass industry. Domination and output restrictions by the trade unions, lack of enterprise by manufacturers, low wages in certain Continental countries, coupled with lack of import duties in the United Kingdom and heavy tariffs abroad, are all causes alleged to have retarded the industry's progress in this country.

It can scarcely be doubted that foreign tariffs have operated greatly to the disadvantage of the British glass industry during the period under review, when such tariffs amounted to from 20 to as much as 80 per cent. of the value of the goods. Particularly heavy was the McKinley tariff in the U.S.A. with duties between 60 and 80 per cent. Sweden, Germany, France, Switzerland, and the U.S.A. all protected themselves by tariffs.

I have endeavoured to obtain some clear evidence of the extent of the change since 1850 of this country from an exporting to an importing nation. In order to eliminate the variation of values over this period, I have adopted for consideration, the ratio of exports to imports for each year and drawn a curve so as to show the variation of this ratio during the seventy years from 1851 to 1920. The numerical values from which the ratios are derived are contained in Table XI.[*] :—

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* H. de Fontenay, *Bulletin de la Société d'Encouragement pour l'industrie nationale*, 1877.

† G. Horn, *Die Geschichte der Glasindustrie und ihre Arbeiter*, p. 70.

Table XI.

Glass Exports from and Imports into the United Kingdom in Thousands of Pounds.

Year.	Exports.	Imports.	Exports/Imports.	Year.	Exports.	Imports.	Exports/Imports.
	£1000	£1000			£1000	£1000	
1851	328	—	—	1886	970	1545	0·63
2	379	—	—	7	1021	1674	0·61
3	518	—	—	8	1109	1907	0·58
4	573	92[†]	6·22	9	1147	1782	0·64
5	507	83[†]	6·08	1890	1065	2085	0·51
6	582	117[†]	4·98	1	1013	2300	0·44
7	659	122	5·42	2	885	2434	0·36
8	569	148	3·84	3	766	2443	0·31
9	607	232	2·62	4	715	2685	0·27
1860	653	244	2·68	5	790	2475	0·32
1	590	345	1·71	6	892	2742	0·33
2	644	408	1·58	7	871	3007	0·29
3	759	434	1·75	8	885	3285	0·27
4	762	556	1·37	9	916	3209	0·29
5	745	630	1·18	1900	1034	3200	0·32
6	806	713	1·13	1	1057	3530	0·30
7	803	804	1·00	2	1098	3697	0·30
8	789	920	0·86	3	1102	3727	0·30
9	886	922	0·96	4	1010	3379	0·30
1870	833	931	0·89	5	1107	3399	0·33
1	878	995	0·88	6	1278	3269	0·39
2	1122	1207	0·93	7	1400	3049	0·46
3	1343	1461	0·92	8	1356	2669	0·51
4	1184	1587	0·75	9	1372	2780	0·49
5	1068	1719	0·60	1910	1573	2920	0·54
6	917	1860	0·49	1	1684	3054	0·55
7	854	1908	0·45	2	1821	3281	0·56
8	756	2050	0·37	3	1814	3449	0·53
9	783	1574	0·50	4	1551	2239	0·69
1880	922	1776	0·52	5	1244	1979	0·63
1	955	1674	0·57	6	1304	2890	0·45
2	1086	1679	0·65	7	1186	624	1·90
3	1084	1606	0·67	8	1052	290	3·63
4	1052	1616	0·65	9	1461	3458	0·42
5	966	1632	0·59	1920	3211	8507	0·38

[*] The figures are taken from the annual *Statistical abstract for the United Kingdom.*

[†] Does not include bottles, but their value in 1857 was only £2,222.

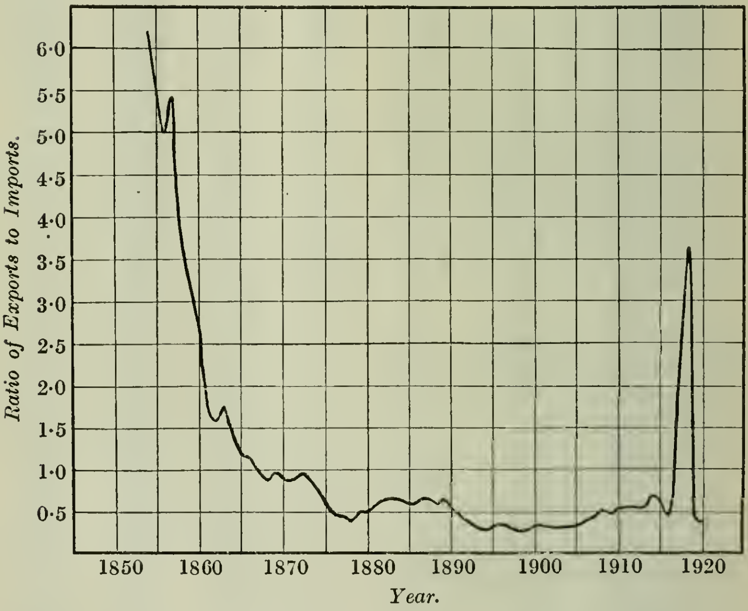
For 1844, the exports and imports in terms of weight instead of value are :—

	Flint and Cut.	Plate.	Crown.	German Sheet.	Other (not Bottles).	Bottles.
	cwt.	sq. ft.	cwt.	cwt.	cwt.	cwt.
Exports	10,734	84,571	7,926	7,520	—	184,628
Imports	1,437	16,768	3,178	171	386	—

In graphical form we see readily how from 1850 the ratio has fallen. All through the century, up to somewhere about 1870, we exported more glassware in value than we imported. From that date onwards we have become relatively more and more of an importing nation. The years 1917 and 1918 were very exceptional. Evidently we managed then fairly successfully to supply our own resources, but in 1919 and 1920 the flood of imports became very great.

Unfortunately, the statistics published by the Board of Trade make it impossible to obtain a continuous record of the progress of our trade in any one particular branch. For some periods, for example, bottles are quoted by the cwt., at others by the gross, at still other times they are lumped with other glass.

Curve showing value of the ratio $\frac{Exports}{Imports}$ *(glassware only) for the United Kingdom.*



One or two other types of glassware present somewhat similar difficulties when an attempt is made at analysis. It is most unfortunate that some definite standard has not been maintained by our Board of Trade in the past so as to enable those who are interested in the industry and its progress to detect clearly at what stage decline sets in or marked advance begins. Glass manufacturers would be the better for a definite annual return of the state of trade and the prospects which any one branch appears to offer. Few things were more surprising to myself during the war, especially when demands were being made by glass manufacturers on various Government Departments, than the almost entire absence of data which they were able to put forward in support of their case. Considerable progress certainly resulted in the collection of statistics for the industry during the later years of the war period, but even now there is much room for improvement.

Even the Census of Production carried out in 1907 is disappointing in information or lack of information which it supplies concerning the industry. The statistics of the glass industry are, in fact, lumped together with stone, roofing felts, and miscellaneous trades. We are informed, however, that in 1907 the total production of manufactures of glass amounted to £4,978,000, whilst lenses and optically worked goods were valued at £78,000. The number of employees for the glass industry alone and all the other details which one finds so admirably set out in the returns of the United States Industrial Census as far back as 1850 are missing.

The term " declining trade " has often been used in connection with the British glass industry before the war. It should be stated, however, that such a description must be considered as true only in a relative sense. True, some branches of the industry declined; true also that certain centres declined, but there were outbreaks or increases elsewhere. Moreover, although the number of works diminished, the census returns show a distinct increase in the number of persons employed. Further, the year which saw the Tariff Commission, before which many glass manufacturers gave evidence, as well as the fifteen years preceding that date, were undoubtedly disappointing to the trade. What is certainly true, however, is that other countries went ahead much faster. Whilst British exports were more or less stationary or even diminishing over one portion of the period, imports were steadily increasing to a very considerable extent. Certainly the export trade of Belgium, Germany, Austria, France, and the United States was increasing very appreciably in this same period as will be evident from the following tables.*

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* The tables for Belgium, Germany, Austria-Hungary, and France are those contained in the report of the Tariff Commission, 1907. I am given to understand they have been checked by the Statistical Department of the Board of Trade and may be taken as correct.

Tables XII.

Average Annual Exports of Glass from Belgium in Thousands of £.

	1891–5.	1896–1900.	1901–5.
United Kingdom	687	1,334	1,340
Germany	48	101	76
France	61	111	95
Holland	192	144	178
Turkey	63	75	80
United States	281	304	420
Argentina	54	98	97
Brazil, Chile, Mexico, Peru, and Uruguay	66	92	105
Japan	18	88	118
Canada	43	79	125
Australia	28	81	95
Cape Colony	3	13	27
British Indies	83	137	138
Other Countries	299	544	543
Total to all countries	1,926	3,201	3,437

Table XIII.

Average Annual Exports of Glass from Germany in Thousands of £.

	1891–5.	1896–1900.	1901–5.
United Kingdom	421	458	540
Belgium	114	180	246
France	251	242	176
Holland	95	110	126
Austria-Hungary	95	88	108
Switzerland	93	111	119
United States	372	221	288
Argentina, Brazil, Chile, Mexico, Peru, and Uruguay	154	232	302
British North America	27	22	39
British South Africa	7	14	24
British Australasia	12	26	31
British East Indies, etc.	42	57	62
Other Countries	395	385	546
Total to all countries	2,078	2,146	2,607

Table XIV.

Average Annual Exports of Glass from Austria-Hungary in Thousands of £.

	1891–5.	1896–1900.	1901–5.
United Kingdom	173	292	357
Germany	382	528	481
Hamburg	357	257	262
France	163	154	151
Holland	71	110	120
Italy	71	73	82
Turkey	53	58	73
United States	55	154	165
British India and Ceylon	25	79	219
Other Countries	283	294	311
Total to all countries	1,633	1,999	2,221

Table XV.

Average Annual Exports of Glass from France in Thousands of £.

	1891–5.	1896–1900.	1901–5.
United Kingdom	269	422	471
Belgium	304	352	487
Germany	59	61	83
Switzerland	43	52	60
Spain	56	46	39
United States	33	36	37
Argentina and Brazil	51	55	87
Algeria	78	82	101
Other Countries	264	311	359
Total to all countries	1,157	1,417	1,724

In regard to the United States, an American writer, G. B. Curtis,* referring to the industrial development of the United States, states that: "It was during this decade, namely, 1860 to 1870, that protection was for the first time in our history extended to industries for the manufacture of silk, linens, chemicals, pottery, glassware and finally resulted in making the United States the greatest manufacturing nation of the world." This writer undoubtedly had a bias towards protective tariffs; but a tariff of 60 per cent. speaks for itself. It is very clear that from 1860 onwards, as shown in the appended table, glass manufacturing in the United States began to be of first class importance.

These tables make it perfectly clear that this country lagged very much behind several other important glass-producing countries, especially during the period from 1890 to 1905.

It ought to be noted that so far as this country is concerned, the exports of glassware subsequent to 1905 began to take once more an upward trend, and increased from £1,107,329 in value in 1905 to £1,813,765 in 1913. Unfortunately, the imports did not diminish correspondingly, but continued to increase. Nevertheless, there was some revival of trade, and a Board of Trade report † in 1913 in regard to the flint glass and allied trades stated that the previous six years had been a period of great activity with not much unemployment.

Thus, the period so disappointing in many respects to its best friends closed on a distinctly more hopeful note.

I should fail to do my duty as a Yorkshireman by adoption if I did not make mention of the fact that in 1887 Ashley, of Ferry-

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* G. B. Curtis, *The Industrial Development of Nations*, 1912, Vol. III, pp. 11 and 175.

† *Manufacture of Flint Glass and Allied Trades*, report on Birmingham trades prepared for Juvenile Employment Exchange, R. S. Smirke, pub. H.M. Stationery Office, 1913.

Table XVI.

*Comparative Summary of Glass Manufactures of U.S.A.**

	1831.	1850.	1860.	1870.	1880.	1890.	1900.	1905.
No. of Establishments	—	94	112	201	169	294	355	399
Capital	—	3,402,350	6,133,666	14,111,642	18,304,599	40,966,850	61,423,903	89,389,151
Salaried Officials, Clerks, etc. ...	—	—	—	—	—	1,095	2,268	3,040
Workpeople	1,800	5,668	9,016	15,822	24,177	44,829	52,818	63,969
Value of Products $	2,501,000	4,641,676	8,775,155	19,235,862	21,154,571	41,051,004	56,539,712	79,607,998
Building Glass $	1,001,000	—	—	—	5,915,618	13,928,296	17,096,125	21,697,861
Pressed and Blown Glass $ ...	—	—	—	—	7,568,520	18,601,244	17,076,125	21,956,158
Bottles and Jars $	200,000	—	—	—	5,670,433	8,521,464	21,676,791	33,631,063
Other Glass $	1,300,000†	—	—	—	—	—	690,562	2,322,916
No. of Pot Furnaces	—	—	—	—	285	564	451	398
No. of Tank Furnaces	—	—	—	—	—	—	206	366
Raw Materials Used [Value] $	—	—	—	—	—	—	16,731,009	26,145,522

* Compiled mainly from the Census of Manufactures, Glass, and Clay Products, U.S.A. Bulletin 62, Department of Commerce and Labour, Washington, 1907.

† Flint Glass.

bridge, constructed the first glass bottle machine and set all the world agog by achieving what, until then, had been deemed impossible. The fruit of Ashley's work has almost been too great to conceive. British machines similar to that of Ashley found their way to the United States and there fired the ambitions of several inventive geniuses, and the result has been in this last twenty years that the glass bottle industry has been revolutionised. Some modern glass manufacturers, indeed, have said that the magnitude of their works is rather to be measured by the fewness rather than by the number of workers employed. We can at any rate date the beginning of this machine epoch from that period of struggle through which the British glass industry passed.

The War Period and Afterwards.

We are still too close to the period of the war to be able to say at all clearly whither its results are leading us in the industry. Yet it is certain that not only the historian of fifty years ahead, but also ourselves, will agree in admitting the violent shaking of dry bones which lay in the valleys inhabited by the glass-makers. And when the dry bones were shaken, very happily some new blood went to the make-up of the corporate body of glass-makers.

What we do know for certain is that the greater the difficulties with which manufacturers were faced the more were they forced to think, and out of that period of hard work an instrument has been forged for the industry which, given normal conditions operating between nations, would be of no small power for this country.

We all know full well how certain industries had to be created; the production, for example, of scientific glassware, such as flasks, beakers, and all other types of apparatus ungraduated or graduated, almost all of which had been imported before the war, had now to be made, and in very large quantities, in order to supply, not only the scientific institutions which were important customers before the war, but also the innumerable laboratories set up to control all kinds of war munitions. Optical glass now needed in a vastly increased quantity for naval and military purposes had to be provided. The lampworking industry, which did not exist as an industry, or, at any rate, was a wholly negligible quantity, assumed enormous dimensions and supplied all sorts of surgical glass instruments, mine horns, and general scientific ware. Some idea of the magnitude of the advances made in this direction will be realised when I say that for the twelve months' period which covered the later stages of the war and ended on November 30th, 1918, in the class of scientific glassware articles no fewer than 2,319,142 such articles were made at the furnace, 39,156,324 lamp-blown articles were made, and more than one million lb. of glass tubing and rod. In 1914, the whole production of such articles could be reckoned practically nil.

In regard to illuminating glassware, the electric lamp bulb, a very important article in many ways during the war, had to be developed. In 1914, probably about four millions had been produced in this country from existing works. In the year in question, however, the development had been so considerable that the output was more than tenfold, the actual figures being 43,217,915 in addition to 1,126,323 lb. of glass tubing and rod required for use with the lamps. Various other types of glassware were developed, and all this did not seriously hinder the production of bottles and jars, of which no fewer than 557,842,123 were produced, of a total value of £3,916,254.

We stand to-day, as the result of the great efforts made during the war period, with a much more thoroughly equipped industry than at any period in its existence. At the present date, no doubt the outlook in trade is not cheerful. It is only too easy to sit down and conjecture up all the forces operating against its further development. The question of the exchanges is one under which the glass industry is labouring heavily, but if our politicians cannot settle this question by bringing peace to Europe, then not only the glass industry, but other industries with far greater financial resources cannot look forward to healthy existence.

It may be also that the inevitable development which has taken place and is taking place in the glass industries in our Colonies, namely, South Africa, Australia, and again India, as well as in other countries abroad, notably Japan, China, and South Africa, appears to have restricted the market for goods just at a time when our productive capacity has reached its highest point. For such who wonder where our products are to find a sale, I would suggest a study of the American methods; for in that country not only is production enormous but the domestic consumption is correspondingly great.

I have before me a copy of a new publication called *The Glass Container*. It is the organ of an Association called the Glass Container Association, financed and run by glass manufacturers and others who desire above everything to increase the use and sale of glass bottles and jars. The publication in question has articles on the sterilisation of milk, the increased cleanliness obtained by delivering it in sealed bottles, the enhanced appearance of packed fruit, tomatoes, etc., when enclosed in glassware instead of in tins or cardboard. Attractively written and widely distributed, it cannot fail to gain converts for the use of glass.

In our country the sale of milk in bottles is in its infancy and is bound to be developed sooner or later.

Then, too, consider how insanitary are the ways in which many of our provision shops, confectioners, and the like, expose their goods. One of the improvements, to my mind, during the war, was that foodstuffs were considered too valuable to exhibit in a shop window and their place was taken by tins, bottles and even by unalluring dummies. There has been a reversion to a bad habit latterly. No one who passes along the meaner streets of our thickly populated cities and reflects on present habits can fail to recognise, not only how much more attractive windows might be made with foodstuffs covered suitably with well designed glassware, but also how considerably might be the improvement in health. Even in well-patronised restaurants one has seen cold meats, fruits, and many otherwise attractive goods uncovered all through the busiest hours of the day, and custom appears to decree that this shall be the fashion. It would not be difficult, if the glass manufacturer set about it in earnest, to write up a fearful account of the many-headed hydra, reptiles, and bugs that infect food not protected by glass and, on the strength of the fright so administered, soon work up a trade the extent of which might be enormous.

As to creations of art in glass, I venture to think there are few lovers of the beautiful who do not find elegance of form enhanced when it accompanies a body of crystal glass. The taste for such glassware, I believe, is rapidly growing and should be exploited to the full by our manufacturers.

I trust I may be forgiven for this short digression into a field into which I may be supposed to have no business; but the whole trend of this address is to suggest that there is no need to lose confidence, even if many other countries are making attempts to become self-supporting. There should still be plenty of scope for the development of the glass industry. The many different novel uses for glass, for example, as dishes for cooking purposes, all are suggestive for further enterprise.

I am aware that my main duty is to teach and to make new knowledge; to go on learning, in fact, and having learned, to go on teaching.

I might have confined my address to my learned colleagues and other technically qualified members, but I want what I have to say to have a wider appeal. At any rate, it is my wish that we who are engaged in the glass industry shall have a somewhat more intimate acquaintance with its development and its possibilities in this country.

If anyone is tempted to feel serious discouragement with the present position before us, I would ask him to reflect on what has been accomplished in the last five or six years, and after taking stock of our assets I believe most people will still admit, unless peace is long to be denied to Europe, that we possess a very excellent opportunity.

The glass industry in this country to-day has an authorised capital which I estimate at £16,000,000. If this amount does not seem very large, I would add that many old-established firms have managed to rub along on capital which to-day would be deemed entirely insignificant, especially when new companies have to be floated. Of the amount stated, at least four-fifths is fully subscribed, and in addition there is at the present time a debenture holding of at least £3,000,000.

In these calculations, I include only factories producing glass, and not the very large number who are given over to its working, whether as lenses, prisms, and the many forms of requirement for scientific instruments, cameras, etc. Also excluded are the large numbers of glass cutters, bevellers, stopperers, grinders, and lampworkers. Many branches of industry depend on glass for part or the whole of their raw materials.

Next, I estimate that if all the existing furnaces in the United Kingdom were in full normal operation they would produce in round figures 790,000 tons of glass per annum, and use in the process nearly $1\frac{1}{4}$ million tons of coal or its equivalent in terms of coke, oil, or coal gas. The estimated capacity of the several areas in the country is set out in the following table :—

TABLE XVII.

Estimated Annual Capacity for Production and Coal Consumption in U.K. with all Furnaces in Full Normal Operation.

	Tons of Glass.	Tons of Coal.
Lancashire	161,760	229,640
London and Home Counties	172,560	203,040
Midland area	59,760	97,920
Yorkshire	298,760	517,680
North-east coast	36,960	71,280
South-west area	5,040	8,640
Scotland	54,240	86,880
Totals	789,080	1,215,080

I believe that by alteration of methods in some of these factories the productive capacity might even be made nearly 50 per cent. greater than stated in the above table; indeed, very great advances have been made in the rate of production since 1915, and I know of tank furnaces which have yielded 280 tons of glass per week at an expenditure of only 160 tons of coal, including that used for annealing as well as for melting. This represents an enormous advance towards efficiency in this country and several factories are making great progress of a similar character.

In regard to furnaces, what I have said already touches only the fringe of development. There have been during the period 1915 to 1921 erected, to my knowledge, in this country no fewer than twenty-seven new recuperative pot furnaces, containing 193 pots; six regenerative pot furnaces, containing forty-two pots; two other furnaces holding twelve pots, and five other pot furnaces or other working furnaces in the flint glass industry. There have been many pot arches erected. So much for the flint glass industry.

For the production of glass in huge quantities in tank furnaces, very great changes have been effected. I have a list of thirty-eight completely new tank furnaces in the period in question, and most of them are of large capacity. In addition, quite a large number have been modified in construction. There have been fifty-two new modern lehrs or annealing furnaces erected and sixteen Owens pot furnaces for use with the Owens machine. Further, modern producer plants have been widely adopted and my record contains a list of between forty and fifty entirely modern producers, quite a number of them of the mechanical type with stirrers or agitators.

Turning to machinery, any old-time glass manufacturer, could he return to this life, would be amazed at the revolution which is rapidly occurring. In the flint glass industry alone, some twenty-five highly productive machines, either fully automatic or semi-automatic, have been introduced. In regard to the production of bottles, jars, and general containers, the advance is very great. There have been sold in this country since 1915 more than 100 semi-automatic machines of very great capacity, namely, the O'Neill, Miller, Lynch, Hartford-Fairmont, Graham, Daubenspeck, and Pyle, and some two dozen fully automatic machines of the Owens type; and most of these machines have been put into operation. In the United Kingdom prior to the war there were about six Owens machines, and of the other types which I have mentioned none at all.

The glass feeding machines for converting the semi-automatic into fully automatic machines have now been introduced into at least eighteen factories; these feeding devices are of varied character, including the Brook, the Macaulay, the Hartford-Fairmont, the Miller, Rankin, Daubenspeck, Pyle, Clegg, and Pitt, and one is glad to note that, although we owe practically all these contrivances to America, British engineers are at any rate beginning to step in.

Nor is it only for its own sake that the great development of the past few years is important. Reference has been made to the many industries dependent for a supply of glass in some form or other as their chief raw material. It could be argued, of course, that many of these could purchase their raw material abroad. Unfortunately, although most of them are not in favour of doing so, such a course would be possible in the case of a breakdown of the manufacturing industry.

But it is not these industries alone which regard as essential a prosperous glass manufacturing industry; for there are quite a number of others. I have stated already that nearly 1¼ million tons of coal would be consumed per annum in this country if all the existing furnaces were in normal operation. Raw materials of other kinds furnish employment and wages for a very large number of additional workpeople. The amount of soda-ash, for example, which would be consumed in normal operation would scarcely be less than £1,000,000 in value at current market prices.

At the outbreak of war much of the sand employed was imported. Unfortunately, since the war there has been reversion to importation. This is not wholly due to having no deposits which might be capable of exploitation if only railway charges were not so excessive. Nevertheless this country, which supplied no sand for making colourless glass in tank furnaces in 1915, now is supplying already at the rate of some 20,000 tons per annum, with a growing demand. This is but small, but despite our rather unfavourable resources in good sand as compared with Continental countries and America, there is considerable scope for development.

Of limestone, both calcium carbonate and dolomitic limestone, we have enormous resources in this country for all kinds of glass, and, indeed, are entirely self-supplying. Up to three years or more ago it was a matter of some concern to those who were proposing to make colourless glass in tank furnaces whether or not the supply of pure limestone of very low iron oxide content was to be found in this country. That problem has now been solved. There are two firms in this country now capable of supplying an exceedingly pure material, thoroughly well prepared for the glass industry, at a reasonable cost.

The various forms of lead oxide are manufactured in this country and so also are many of the minor constituents used in glass-making. Unfortunately, the development of a native potash industry has not proceeded further since the mineral supplies abroad once again became available. Nevertheless, all things considered, we are by no means unfortunately placed for our raw materials. The fireclay and silica industries also depend in a very large measure on the prosperity of the glass industry to maintain a healthy existence. The amount of refractory materials supplied must have grown very greatly during the past few years. One old-established firm alone supplied in 1920 a quantity 400 per cent. greater than in 1915.

Mention of refractory materials brings me back again to the subject of furnaces, and, as an indication of development, I would like to point out that prior to the war there was to my knowledge only one firm in this country which devoted itself to any considerable extent to glass-furnace building. Many furnaces were built by the works employees to traditional design. At the present date, however, there are no fewer than seven firms who devote themselves in a large measure to the design and construction of modern glass furnaces.

Rule of thumb methods are rapidly giving way to scientific. It could scarcely be otherwise in view of the entry of trained minds into the glass industry in these last five or six years. Prior to the war it would have been difficult, I believe, to have found in the whole of the factories of the United Kingdom a score of trained chemists and engineers. At the present date there are at least fifty; and by trained chemists and engineers I mean graduates in the case of chemists or of equivalent standing, and in the case of engineers, men who are either associate members or full members of the engineering institutions. Not only have we this much greater number inside the factory walls, but in three institutions in this country there must, in addition, be some seventeen to twenty other workers wholly engaged on research work on glass where not one existed before 1915.

We have in this country now a University Department engaged in the training of young men to a standard of attainment at least equivalent to that which has been possible for years in the better established branches of engineering, metallurgy, and applied chemistry. These young men are already leaving the University and looking out for enlightened employers to make use of their services.

The employers who engage them are those who are going to make most progress in the coming ten years. We have also research institutions like the Glass Research Association and the National Physical Laboratory, in addition to the research institute for glass at Sheffield; and the money for research which the Department of Scientific and Industrial Research has put at the disposal of the glass industry has been on a very generous scale indeed.

Finally, we have a scientific Society comprising now nearly 700 members, grown up and developed since 1916. Up to the end of last year, that is, after five years of existence, no fewer than 143 wholly original papers had been read before the Society or contributed to its pages, whilst abstracts of 1714 papers on all sorts of subjects had been issued. It is impossible to calculate the enormous influence on the general progress of the glass industry of all this work and all this information. A single research may mean the saving of thousands of pounds in the industry during a year, and quite apart from the benefit calculated in such terms there is the value which the steady and persistent pressure of new results exerts in producing thinking amongst manufacturers.

The industry stands to-day as a growing lad, the immediate son of somewhat impecunious and old-fashioned parents, but with forbears of no mean stock. It has no resources to fall back on save its own energy and enterprise; in its half-grown state it has plenty of imperfections, and lacks experience and the touch of confidence. It stands in need of faithful criticism, but equally in need of sympathetic help. Those of us who look on as godfathers and godmothers, brothers, and sisters, or even distant cousins, helping to guide its steps, may need to give, perhaps, something more than advice and be content to understand that it may not make our fortunes. But there is in it something more than a spark of life and no small power, even if at present lying latent; and some of us believe that the present hard time through which it is passing may in the long run only serve to harden it and make it more enduring when it comes of age.

In conclusion, I should like to take this opportunity of expressing my hearty thanks to a number of friends who have assisted with information embodied in this address: to Mr. S. W. Morrison, O.B.E., and the librarian of the Board of Trade, and to the Assistant Registrar-General, Register Office, Somerset House, London, for statistics; to Mr. J. D. Cauwood, M.Sc., for helping to search Somerset House records, and to Mr. Duncan Webb. To my colleague, Mr. G. S. Duncan, M.A., B.Sc., I owe special acknowledgement for ever willing help over a considerable period in assisting me to dig for information in a field where the buried treasure is often rather well concealed.

Department of Glass Technology,
The University, Sheffield.

IX.—*The Melting of Glass. Part II.*

(*General Discussion at the Manchester Meeting, February* 15*th*, 1922.)

EDITORIAL INTRODUCTION.

THE first discussion on this subject was not only keen but also brought to light many points needing investigation. At least one of the particular matters at issue has actually been taken up as a subject for research since the meeting occurred. This alone would make worth while the continuation of such discussions.

Supplementary discussion of the subject proved no less valuable in furnishing a searching test of our knowledge. Several of the questions showed, not only how little we know, but even surprised some glass-makers. Reference may be made particularly in this matter to the question of the standing-off of glasses which to all appearances are already plain. If any members who were not present at the discussion care to advance this subject further by communications in writing the Society will be indebted. Communications should be addressed to the Editor.

The Proportion of Cullet to Batch needed in the Production of Satisfactory Glass.

This subject is one of widespread interest. The discussion centred in the question :

" What is the objection to using a large quantity of cullet? What are the troubles it is likely to cause? If there are any, then what is the safe maximum proportion of cullet to batch? "

MR. J. CONNOLLY said that this was a question which was constantly occupying the minds of a good many glass manufacturers. Personally he did not see that there was any particular advantage in using a large quantity of cullet except under conditions of low temperature. When one had the means of melting a large percentage of batch he considered it was the wiser plan to do so as this course would naturally tend towards a much better glass.

MR. DUNCAN WEBB, jun., said that those engaged in glass works practice could easily state facts which the scientist might be disposed to pull to pieces. Generally, the manufacturer used cullet, or broken glass, in the mixing and melting of glass, for the reason that if cullet were not used the glass would never get rid of those bubbles which were formed in the melting process. The bubbles never got away so quickly from a melting of pure batch as from one derived from a mixture of batch and cullet. He supposed, therefore, that the cullet acted as a sort of flux, making it possible for the small gas bubbles to gather into larger ones and so rise and escape. If, however, more than 50 per cent. of cullet were employed in the mixture, this also tended to keep the "plainness" out of the metal. He would suggest 33 per cent. of cullet and 66 per cent. of batch. He was referring now to flint glass.

Dr. M. W. Travers said they had the view of a practical flint glass manufacturer. Would a tank glass manufacturer now take up the point?

Mr. J. Connolly said he thought the same arguments would apply to a tank-made glass.

Dr. M. W. Travers hereupon observed that one had to remember that there was quite a proportion of tank glass manufacturers who used no cullet at all.

Mr. J. Connolly, proceeding, said that the difference between tank furnace practice and pot furnace practice, generally speaking, was that the tank glass manufacturers often shovelled in unwashed cullet, which went to the tank under all sorts of conditions, whereas the flint glass manufacturers washed their cullet. One was bound to assume that cullet used in the first-mentioned circumstances seriously interfered with the colour of the glass. At his own works the cullet always had been washed and inserted in much the same way as the flint glass manufacturers put it into their pots.

Mr. A. S. Giles said that in his experience if the glass were made from batch alone one only encountered those very minute, almost imperceptible, bubbles which looked very much like dust in the glass, but the viscosity of the glass, when gathered either for blowing or pressing, was not so suitable. The glass did not hold together so well as when cullet was added. It was softer and much more difficult to gather, however much the percentage of lime was raised or lowered. The addition of a small percentage of cullet was a great advantage for these reasons.

Dr. M. W. Travers said it was well known that practice was very variable. Some manufacturers used batch only, some cullet only, and some a mixture of the two. It had to be remembered that in this country there were still a good many small tanks and skittle-pot furnaces in which cullet only was used and in many of these cases the manufacturers might not even know how to mix a batch. He had himself made, in a 38-in. pot, a glass that was melted entirely from cullet. He had also made glass entirely from batch. With a soda-lime glass made from batch (the glass being used for tube drawing), a peculiar thing occurred. On one or two occasions he found that the glass from the batch alone appeared unduly fluid. He believed that flint glass manufacturers practically always used cullet. He did not know whether anyone could lay down a definite rule as to how much cullet should be used. He would be inclined to say that this depended very largely on two factors: the nature of the glass that was being made, and the temperature at which it was being worked.

Prof. W. E. S. Turner emphasised what Dr. Travers had said with regard to the large number of small manufacturers of glass bottles who use nothing but cullet. Perhaps he ought to qualify that statement and say that, in some cases, nothing but a mixture of cullet, jam, tomatoes, and straw. At any rate, the glass contained no batch, unless it was added sometimes at the week-ends. There were, therefore, the two extremes to deal with. There was another factor which often determined the amount of cullet used, and that was the breakage that took place on the works. Where manufacturers broke about 60 per cent. of their production they naturally tried to use this up as cullet. But there were two points, to his mind, which required special care. A number of things had been alleged to cause glass to have a different nature when cullet was used. It was said that such a glass had different working properties, and again that it was brittle. He could not quite associate this with any considerable amount of volatilisation of the alkali. It might be so, but he thought it was rather doubtful. In regard to tank furnace operations, there were two considerations to be borne in mind: first of all, the type of glass that was to be made and the colour that was required. When absence of colour was required, it was obvious that the amount of cullet used should be kept down to a fairly small amount, because glass which had once been through the furnace naturally must have picked up a considerable amount of iron oxide. At any rate, it would contain a higher proportion of iron oxide than the fresh batch materials. Therefore, if absence of colour was to be ensured, the cullet must be reduced to a comparatively small amount. What that amount was would naturally be a matter for discussion, but in his view the amount should be somewhere about 25 to 33 per cent. of the total weight that went into the furnace. By total weight he meant batch plus cullet. The second consideration was that for constancy of conditions in the tank furnace, whatever amount of cullet it was decided to use, the proportion of cullet must at least be kept constant. It should not be 25 per cent. one week and 40 per cent. the next. If the working conditions of the furnace were to be kept constant, as must be the case nowadays for machine work, the materials fed in must be kept uniform.

When glass was melted in pots, the conditions to be observed might vary appreciably from glass to glass in a manner not yet capable of being defined; but the two general considerations referred to must hold for any one glass.

MR. F. G. CLARK said that so far as a glass containing 12 to 15 per cent. of lead oxide in the finished glass was concerned, it was quite possible to make a good lead glass from batch alone, that is, without employing any cullet. It was the usual practice at the works which he represented. It was also possible to make a good glass from batch alone in the case of a soda-lime glass, although it was true that in such a case one had to wait a little longer for the fining to take place. In his own works practice a little cullet was usually added—approximately 10 per cent. of this cullet being of the same composition, and consisting of broken up stoppers. So far as green glass was concerned, he believed that cullet was often added because, more particularly in the case of hand-blown work, it was not possible to get along nearly so quickly with the pure batch metal; that is to say, the glass did not melt so quickly. In this case a very much bigger proportion of cullet than batch was used, for the main reason that one could get along very much quicker by this means.

MR. W. BUTTERWORTH, jun., observed that batch metal was naturally much harder to found, but was softer in working than a metal made from batch and cullet. The fact that cullet made for hardness in working and brittleness in the final product was popularly ascribed to a loss of alkali from the glass which somehow occurred in successive melts. A contributory cause might be that in repeated meltings the cullet would have further chances of dissolving the fabric of the pot, and would therefore contain an increased proportion of silica and alumina, both of which substances (at any rate the former) conduce to hardness.

MR. G. SIMPSON said that in one case in his experience dark metal had been melted in a tank furnace using about 50 per cent. of cullet, mixed with the batch. The result had been the production of cordy metal. The bottles showed a sort of big wave in the surface. The only way in which it was possible to get over this trouble was by reducing the amount of the sand used. Why, when using 50 per cent. of cullet, a fault like that should be experienced, he did not know.

The Advantages and Disadvantages Attending the Use of Salt-cake as a Constituent of Glass Batches.

This question, which is continually cropping up, was presented by one member in the following form :

" For a window glass averaging 73 per cent. of silica, 14 per cent. of lime, 13 per cent. of soda, are there different physical properties, viscosities, difficulties in hand-working, due to the nature of the batch, according as the source of alkali was either soda-ash or salt-cake? Should window glass made with soda-ash be inferior to window glass made with salt-cake, or loss workable in glass gathering? It would seem apparent that the use of soda-ash as a constituent of the batch is less corrosive of the tank blocks. Also less clouding of the window glass cylinders occurs when reheated in the furnace flame containing sulphur and a soda-ash batch is consequently worthy of commendation."

MR. R. L. FRINK (*communicated*): The experience of American manufacturers would seem to indicate that a mixture of soda-ash and salt-cake in the proportions of two parts of soda-ash to one of salt-cake give results that met all the requirements of good window glass manufacture.

MR. P. HALLER said that although the subject-matter of the question related specially to window glass, it applied also to one used for bottle-making. There seemed to be no doubt that salt-cake would have more effect on the tank-blocks than would soda-ash, for in most tank furnaces the salt-cake melted and rose to the top of the melting batch. Although molten salt-cake was less corrosive of the tank-blocks than was soda-ash under the same conditions, the fact remained that the salt-cake got there and the soda-ash did not, so that if salt-cake were present, unless there was sufficient reducing matter to decompose it at the start of the melting process, it tended to rise to the surface.

MR. J. CONNOLLY quite confirmed what the previous speaker had said.

PROF. W. E. S. TURNER hoped that someone might have referred to the difference in the working properties between glass produced from soda-ash and salt-cake containing batches. The glass did seem to have a greater viscosity when made from salt-cake than when made from soda-ash. He understood the consensus of opinion amongst manufacturers of window glass was that the batch which contained at least a proportion of salt-cake was preferred, simply because the glass, although being somewhat less fluid, had apparently a slightly longer viscosity range. It was not so soft or fluid, so that in the blowing of the cylinders these could be raised at a rate slightly greater than was the case with a batch in which soda-ash alone was used. The salt-cake glass was often spoken of as being "sweeter." He was not quite sure what that term implied—it seemed to have different meanings in different places. If there should be present any glass-makers who had used both these types of glass, an expression of opinion by them on the subject would be welcomed.

Dr. M. W. Travers said there was one point that might usefully be dealt with, namely, the bluish-green colour sometimes got with the salt-cake batches, but not with the soda-ash.

Mr. F. W. Hodkin remarked that the glass-workers at Sheffield had a unanimous preference for a salt-cake glass. He was not, however, prepared to say that the one type of glass was any softer than the other. It was possible to produce a glass made entirely from soda-ash and one made entirely from salt-cake, and although they might be apparently of the same fluidity, or the same viscosity, yet the glass-workers would say that it was much easier to work an article made from salt-cake glass than from a soda-ash glass. The workers' view was that the salt-cake metal was the " sweeter " of the two. It was not more fluid, and it did not appear to be more viscous, but it was a more readily worked material. At a former meeting of the Society, Mr. W. J. Rees mentioned the possibility that the solution of SO_3 in a glass was productive of this quality of " sweetness " in the metal. Whether that was the case or not he could not say, but the ordinary glass bottle-maker undoubtedly seemed to prefer glass which contained *some* salt-cake. As regards the blue colour, mentioned by Dr. Travers, it would be very interesting to devote a whole meeting to this subject, because everybody was intensely interested in it, and very few people appeared to have the same ideas.

Mr. F. G. Clark said that at his works an open pot furnace was at one time used in which a mixed salt-cake and soda-ash batch was employed—two parts of the former to one of the latter. The men complained that they could not work with the soda-ash batch alone. This seemed to bear out exactly what Mr. Hodkin had said. The men did not seem to be able to explain the reason why it was so much easier to work the one type of batch than the other, but in his experience they certainly seemed to be able to get a much better article when salt-cake was used. They were able to marver it very much better, especially in the production of big work. As regards sulphuring in the cylinders, in his opinion this was not due to the sulphate in the glass at all. He thought it was due entirely to the composition of the batch.

Dr. M. W. Travers hoped the discussion was emphasising one important point, namely, that there was, in practice, a real difference between the glass from salt-cake and the soda-ash batches. If they could get that into their minds they would have to look round and try to find some cause for it. The scientific man learned, in the course of his experience, that there were many facts which he could not only not explain, but which were very difficult to get hold of. When the glass-makers, who were expert craftsmen in their own particular line, were unanimous in making a statement, there must surely be something definite about it, and although their mode of expressing it might be somewhat puzzling to the man of science, the latter must make it his business to try to find some explanation.

Mr. F. W. Hodkin said that he might, perhaps, be able to throw some little light on what the glass-maker meant, for he had a chat with a glass-maker on the subject some little time ago. The latter explained to him that when he got the glass on the marver, if it was "sweet" he could feel the touch of it; and he could blow it out more truly. When a batch contained salt-cake there was a sensation in the working of it that was not experienced when dealing with a batch containing no salt-cake.

Mr. W. R. Barker thought that "sweetness" in glass was closely associated with its homogeneity. It was possible to get a greater degree of homogeneity with a salt-cake batch than with soda-ash. A thoroughly homogeneous glass could be blown out better, and because of this it was said to be "sweeter."

The Time Required for "Standing Off."

The inquiry which led up to the discussion was:

"How long prior to working should a melt be maintained at 'plaining' temperature once it is already plain?"

Mr. F. G. Clark said that on first reading this question the answer seemed obvious, namely, to work the glass as soon as it was plain. But what, he supposed, the questioner really meant was with regard to the time the pot should stand to get rid of cords, waves, etc., before being worked. This depended very largely on the amount of glass to be gathered. For a small amount such as 2 or 3 oz. where the gathering iron only dipped say 1 in. into the glass, one hour after taking the stopper down was sufficient, whilst for larger amounts a longer time was proportionately necessary.

The point was to get the lowest part of the metal to which the iron dipped as near as possible the same temperature as the surface.

Mr. Duncan Webb, jun., gave one instance which had come within his knowledge of a glass of specific gravity 2·9, made from a mixture of 57 per cent. of sand, 25 per cent. of red lead, and 18 per cent. of soda-ash, which, although it became plain at nine o'clock one morning, was too soft to work at twelve noon. It was impossible to gather it. The articles to be made were about 4 lb. in weight and this amount could not be gathered. He was called down to the glass-house and he suggested that the glass should be tried again in the afternoon. Even then it was still impossible to gather it, although the temperature had been greatly reduced, and the furnace was comparatively cool. Only after twenty-four hours from the time when the pot was taken down was it quite possible to gather from the glass the articles needed. Although, therefore, we know that it is the general custom to work a glass soon after being plain, there may be instances where it is easier to gather on the second or the third day after the glass has been cooled.

Mr. F. W. Hodkin observed that he could confirm Mr. Duncan Webb's experience. He had recently been melting lead glasses containing, in the finished glass, something like 54 per cent. of silica, 33 per cent. of lead oxide, and 13 per cent. of alkali introduced as soda-ash, potash, or both. Certain variations of the proportions of soda to potash had been tried without any extraordinary happenings. When, however, only soda-ash was used, the glass was so soft that it was impossible to draw tubing from it. Two attempts were made with the glass cooled to about 500° or 600°, but there seemed to be no limit to the extent to which the glass could be drawn out.

Dr. M. W. Travers said that the point raised was a somewhat remarkable one, and it seemed to prove that there was more in glass production than one had been commonly inclined to think.

Mr. F. G. Clark remarked that possibly the surface of the metal might be chilled within a few hours, whereas it might take twenty-four hours to get the glass chilled right through, and it was only then, of course, that it was possible to draw it.

Mr. V. H. Stott said that it was known in connection with the sodium silicates that the properties, both chemical and physical, depended on the length of time involved, as well as on the temperature to which they were taken, and it might be quite likely that these phenomena applied equally to other silicates than the sodium silicates.

The Effect of Different Methods of Charging in Batch on the Homogeneity of the Glass Produced.

The question as framed by a member of the Society was as follows :

" What is the procedure to adopt in order to ascertain the homogeneity of a glass ? Is it better to fill into the furnace batch and cullet separately, or batch and cullet mixed ? "

Mr. F. G. Clark said that he had never heard of anyone filling in batch and cullet separately. They always filled them in together. He referred to pot furnace practice.

Mr. J. H. Bickerton remarked that at the works with which he was associated batch and cullet were at one time added separately. The cullet was put in first because there was no bridge in the tank, and the charging hole was rather a peculiar arrangement. The charge was added from the top of the dog-house, and the speed of the batch falling into the furnace from the dog-house trough sent the fillings sharply to the bottom of the furnace. It was decided, therefore, to put in four or five barrows of cullet first and to charge the batch in afterwards. The charging was performed about once every three hours.

Dr. M. W. Travers said that in connection with tanks he had frequently heard of charging the cullet in first and the batch in separately, the idea being to keep the batch in the region of the flame of the furnace. He had never heard of it being done separately in glass pots.

Mr. J. Connolly said it was his experience that, for all practical purposes, the mixing of the batch along with the cullet certainly facilitated the melting.

Mr. W. Butterworth, jun., supposed that in pot practice the batch and the cullet were invariably mixed together, one reason being that the quality of a glass changed by being repeatedly used as cullet. It got harder, and greener, more iron getting into it. Its general composition also changed. Therefore, he imagined it would be rather difficult to get a really homogeneous glass if the batch and the cullet were put in separately.

Prof. W. E. S. Turner did not think there was any doubt that the better the batch and the cullet were mixed the more complete would be the homogeneity of the glass. He had already seen streakiness produced in coloured glass at one works where the charging was only effected in the furnace about every four hours, this naturally involving a fairly big filling. The trouble occurred largely by reason of the fact that a big charge of batch was first made, and then a big charge of cullet of somewhat different colour from the finished glass. A layering effect was thus produced which was not removed in the course of the passage of the glass through the tank to the working end. He thought it was far better, and was certainly modern practice, wherever it was possible to do so, to break up the cullet fairly small and mix it with the batch quite thoroughly, charging the two into the furnace simultaneously.

The Equipment Needed for the Technical Control of a Window-Glass Tank Furnace.

Time did not permit of the discussion of the question:

"What should be the standard equipment for the technical control of a window-glass tank furnace?"

One reply, however, had been communicated in writing and is therefore reproduced.

Mr. R. L. Frink (*communicated*): Obviously the character of the equipment which would meet the conditions for technically controlling the operation of a window-glass furnace depended to some extent on the character of the fuel used, the design of the furnace, and whether or not the furnace was to be used for machine or hand operation. However, in general, it had been found that good control could be obtained by using a draught gauge and a pyrometer between the stack damper and the air valves, a gauge in the gas flue showing the pressure of the gas at the gas valve, or, better a device for automatically controlling the flow of gas into the furnace; a gauge of sufficient sensitiveness to indicate the change in volume of air entering the air valve; a pyrometer in the working end of the furnace through the crown and another one located through the side wall of the furnace as near to the glass line as convenient. These two were quite essential in window-glass furnaces in order that one might obtain proper control of the gases flowing from the melting to the working end, and of the temperature of the glass at the working end in order to overcome those defects called cold cords or strings.

X.—*Columnar Structure in Sandstone Blocks.*

By John Currie, M.A.

(*Read at the London Meeting, May 17th*, 1922.)

An interesting example of superinduced prismatic structure has recently been observed in sandstone blocks used in the construction of a glass tank furnace. The formation is identical in every respect with that which takes place in Nature, particularly in the case of a columnar basalt, and is, in fact, a reproduction of contact metamorphism on a small scale.

The tank in question was used for the manufacture of green bottle glass. The melting compartment measured 19 ft. by 15½ ft. and was separated from the rounded working end by a fixed bridge. The dead weight capacity of the tank was approximately 84 tons, when filled to a depth of 3 ft. The construction of the tank was on the ordinary lines, the bottom being of fireclay binders built into a series of six arches. Sandstone blocks formed the lowest course of the sides, and these were surmounted by two courses of fireclay blocks.

The sandstones were supplied by Messrs. J. & W. Lowry, Penshaw Quarries, Durham, and measured 36 in. long, 18 in. broad, and 12 in. high. The fireclay blocks were of the same dimensions, so that the depth of metal in the full tank was 36 in.

The tank, which was first built in 1908, was rebuilt in August, 1913, with new sandstones, side blocks, and crown. Since then, the top course of blocks has been renewed every year. During the same period the second course was renewed three times, the last occasion being in April 1921, when it was observed that the sandstone blocks had been corroded to the extent of about 7 in., the original 18 in. being then reduced to about 11 in. thick. Thus, corrosion of the sandstone had been proceeding at the rate of less than an inch yearly. This was satisfactory indeed, but it must be borne in mind that the tank was used for dark metal, and, that being so, the temperature near the bottom, at an estimate, would scarcely exceed 800°. The normal working temperature of the tank varied from 1300° to 1400°, and the depth of metal was only lowered by about 6 in. during each working week, and by about 10 or 12 in. on the few occasions when repairs to the sides were to be effected.

During its last run, commencing in April, 1921, the tank worked very well for about six months, by which time it began to show signs of excessive corrosion in some parts of the sides. On November 13th a leak occurred on the north side whereby the level of the metal was lowered by 7 in. in the course of a few hours. This leak was patched up and work resumed the same day.

By this time it had been decided to convert the tank from dark to pale metal on the occasion of its next repair. That being so, it was deemed advisable to get as much of the dark metal as possible out of the tank before allowing it to cool down. If work was continued there was the risk of a more serious collapse, which might have entailed shutting off the tank at any moment with a full depth of dark metal, the removal of which, after the furnace was cooled, would have incurred arduous labour.

Accordingly, no more batch was put into the tank and work was continued until November 18th, when the metal level stood at 27 in. Ladles were then requisitioned to remove the remaining metal. While ladling was in progress, the tank sprang a leak in the bottom somewhat towards the south side, and about 9 ft. from the back wall. The metal drained rapidly through this leak into the cave below, the level in the tank falling from 27 in. to 9 in. in the course of six hours. The gas was kept on all this time and a full heat of 1300° maintained so as to preserve the fluidity of the metal and allow of its removal both by ladling and by draining through the bottom. However, when the metal level had reached 9 in., part of the crown collapsed directly above the leak in the bottom, and, to avoid setting fire to the roof of the building, the gas had perforce to be cut off.

It may be mentioned here that the metal falling through the tank bottom into the cave beneath assumed a stalactitic formation which rapidly solidified and prevented further flow of the metal. But as each successive column was broken away the flow was renewed with the result that, as already mentioned, the level of metal in the tank was lowered from 27 in. to 9 in. in a period of six hours.

After the tank was dismantled it was observed that the sandstones readily disintegrated into long prismatic columns, many of which were straight, but most of them showing a decided curvature, which helps to explain the method of their formation. These prisms are roughly pentagonal in section, and vary in thickness from half an inch to an inch and a half. The faces of the prisms are not equally developed, and, moreover, some of the columns are trigonal, others tetragonal in form. Similar formations are found in Nature, and when this structure is fully developed, as in the well-known rocks of Fingal's Cave and Giant's Causeway, the columns tend to assume hexagonal forms.

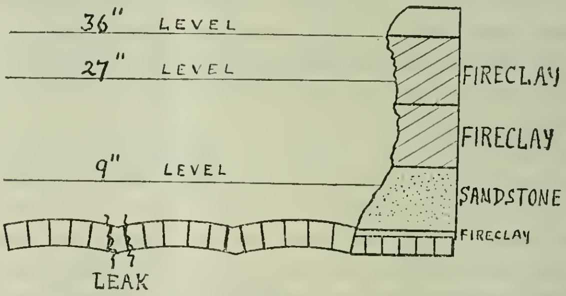

Fig. 1.

Again, many of the columns are incomplete, and taper off to a point in pyramidal fashion; also they are intersected at more or less regular intervals by transverse or cross joints, so that on disintegration the sandstone tends to break up into short columns five or six inches long, some of which are regularly prismatic, others tapering off to a point coincident with the plane of a cross joint.

This prismatic structure is always developed at right angles to the planes of cooling, and a reference to the diagram will explain how the formation took place in this particular instance. In the

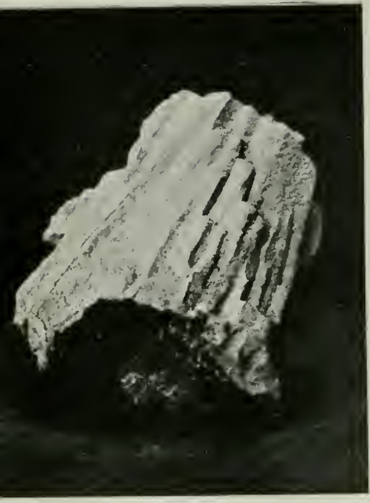

Plate I.

verted portion. Glass surface towards the front.

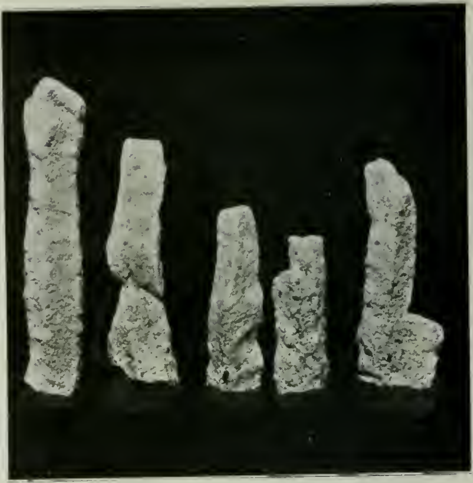

Plate II.

Separate columns.

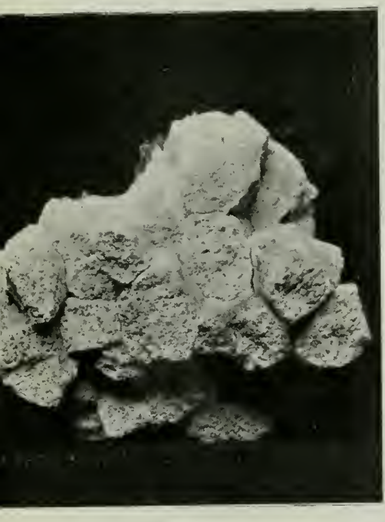

Plate III.

nd view of prisms. Broken along plane of a cross joint. (Same portion as Plate IV.)

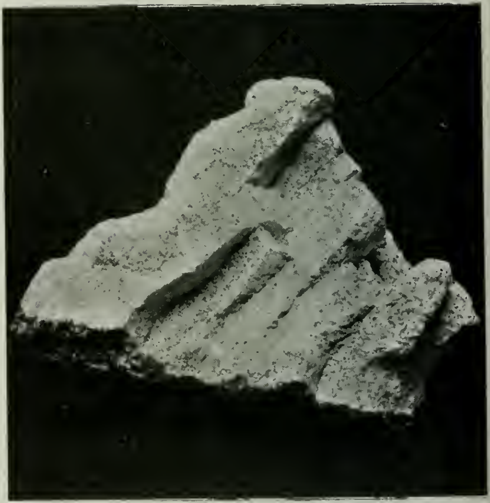

Plate IV.

Same as Plate III. Glass surface at bottom. On right, line of a cross joint.

[*To face Trans., p.* 159.

space of a few hours the sandstones which normally were at a temperature not exceeding 800°, were raised to a temperature of 1300°. Expansion took place rapidly, and then the heat was suddenly cut off. The crown of the tank was open; consequently cooling was rapid, and the sandstones underwent sudden contraction resulting in complete rupture at right angles to the inclined surface of the corroded stones, representing the plane of cooling. Hence the reason for the curved and inclined nature of the columns obtained.

Taking the adhering glass surface as the starting point of the formation it is observed that in many cases several prisms gradually merge into one, trending towards the bottom of the sandstone. It is interesting also to note that the formation has been continued as far as, and distinctly developed in, the thin seam of fireclay binding the sandstone to the tank bottom.

In some parts, however, the fireclay seam is quite intact and, when this is so, it is observed that the sandstone near the bottom shows either a faint trace of columnar structure or else a distinct massive rectangular jointing.

The whole of the evidence goes to prove that the formation started at the point of contact with the glass, and that in this instance, as has already been claimed for similar formations in Nature, columnar jointing is distinctly related to the planes of cooling.

A reference to the accompanying photographs will give a better idea of this prismatic structure.

Plate 1 shows a portion of sandstone block in an inverted position, the adhering glass being towards the bottom facing the camera.

Plate 2 represents a few of the prisms as they appear when detached from the stone.

Plate 3 gives a view of another portion of a block broken off approximately along the plane of a cross joint shown on the right. The glass surface is at the bottom.

Plate 4 is an end view of the preceding specimen, the plane of the cross joint facing the camera. Some idea is obtained from it of the development of the sides of the prisms.

Dr. J. W. French has obtained specimens of a similar formation by the rapid cooling of a pot of optical glass. In this instance the sudden contraction caused the rupture to commence near the centre at the surface of the glass, the prismatic formation of the glass extending from that point radially towards the bottom of the pot and was continued in the clay forming the pot itself.

The two cases, although essentially of a different nature, are very similar as to the primary cause and final results, and form an interesting comparison.

The thanks of the writer are due to Dr. J. W. French, of Messrs. Barr and Stroud, Ltd., Glasgow, for taking the photographs here shown.

Scottish Central Glass Works, Ltd.,
Kelliebank, Alloa.

XI.—*The Mediæval Glass of York Minster.*

By The Very Reverend W. Foxley Norris, D.D.,
Dean of York.

(*Report of an Address at the Sheffield Meeting, April 26th,* 1922.)

The Dean began by saying that he by no means claimed to be an expert. He then introduced his subject by stating that it was scarcely necessary to remind his hearers that they could legitimately claim to have at York a priceless collection of mediæval glass, not only from the archæological and antiquarian point of view, but also from an architectural aspect. They had, he supposed, the finest thirteenth, fourteenth and fifteenth century English glass in existence. This collection was not only æsthetically but literally and materially priceless. To give some idea of the material value of this old glass, it was instructive to recall the fact that in March last, at a sale of curios and artistic treasures in New York, a panel of fourteenth century English glass, 30 inches by 31 inches, changed hands for £18,500. Now at York Minster they possessed between 25,000 and 30,000 square feet of such glass. If sold at a similar rate, this would work out at something over seventy million pounds. It was true that people would not buy in such large quantities, and it was also true that the York windows were not for sale.

The apathy of the public towards the restoration of the glass of our old cathedrals was probably due to the fact that they did not realise what a unique treasure it really was.

In making the bold claim that the stained glass of York Minster constituted the finest collection of thirteenth, fourteenth and fifteenth century glass in existence, he did not think he was in any way exaggerating. There could surely be nothing finer in the world than, say, the "Five Sisters" window dating from the thirteenth century; or the great east window dating from 1405 (a perfect wall of glass 78 feet by 33 feet), the great west window (1317), and others. These, however, were only a few of the one hundred and nine windows of the cathedral, which contained fourteenth and fifteenth century glass, a few only being attributed to the thirteenth century and one to the twelfth.

There were, of course, some very early windows in Canterbury Cathedral, but from what he had been able to gather from those who were versed in such matters, the Canterbury windows, although they were as early as anything they had at York, possibly earlier, were not of quite the same value, because of the fact that the Canterbury windows were made before the art of glass painting in England had reached its zenith. The hundred and nine mediæval glass windows at York (and it must be remembered that there was probably no other cathedral in the kingdom that had more than a dozen) were in many cases actually made and placed in position when the building was originally erected. In the great east window, made by John Thornton, who lived at the end of the fourteenth century, the glass was prepared piece by piece, and every piece for the spot that it occupies. In that window there were two hundred and twenty subjects, and the story went that as Thornton made and inserted each pane of glass or each little portion of a pane, he came into the cathedral, critically inspected his work, and, if he felt dissatisfied with it, scrapped it and began again. An interesting list of the names of the glaziers employed at York Minster from 1371 to 1578 was in existence.

It was important also to remember that practically the whole of the York Minster windows were entirely of English workmanship. One did not allude to this merely from a patriotic point of view, but in the frank belief that there was no finer glass at this particular period than English glass, which had characteristics all its own. There was a quality in the white glass of this particular time which, so far as was known, was not found in any other.

People had often asked how it was that York Minster was rich in its possession of such glass whereas Westminster Abbey and other cathedrals had only a few scraps. The main reason was very simple. It was that Lord Fairfax, who commanded Cromwell's troops during the siege of York, was a Yorkshireman, and he was so jealous for the glass at York that he threatened with death anyone who injured the Minster. It was he who preserved the windows at that critical period, and fortunately they had not been meddled with very much since by architects or anyone else. It was extremely fortunate that the windows were not ruined by either of the great fires which took place at York Minster (1829 and 1840), one of which burned out the choir and the other the nave. It was true that a good deal of the glass was cracked, but none of it was destroyed. Similarly, during the Great War the windows were happily spared. In the first serious raid of 1916, when York had no anti-aircraft defences whatsoever, although a Zeppelin bomb fell within 280 yards of the much-treasured east window of the Minster, causing material damage to property and some loss of life, the window itself was not destroyed. It was really wonderful to contemplate how York Minster windows had been preserved right through the centuries and still remained unimpaired except by the ravages of time.

"I want you to realise," proceeded the Dean, "the enormous size of the windows, because that, of course, has a great bearing on the problem that we are up against to-day. The east window is, roughly, rather larger than a full-sized tennis court. It is all built up of tiny pieces of glass an inch or two in size. From this you can form some idea of the difficulty of dealing with the question of the preservation of that window. Again, in the lantern tower we have some valuable bits of glass. There is a little job that requires to be done there now. A pane of glass has got displaced; it is dangerous and might possibly fall. The job itself will cost approximately £20, but the clerk of works estimates that the scaffolding necessary in order to do the job will cost about £1,100. This illustration may convey to you a better impression of the enormous size of the area to be operated on, the height, and the general difficulties of our work."

The Dean went on to indicate how the incidence of the war had been instrumental in focussing public attention on the subject of the preservation of the Minster windows, a work which had already been taken in hand many years ago by his predecessor, without any public interest being excited. At the beginning of the war, the Archbishop of York was warned by the military authorities that there was danger from hostile aircraft, and it was their opinion that some of the principal windows of the Cathedral should be taken down and stored in as safe a place as possible. The suggestion was acted on, and altogether twenty-three of the windows were taken down and packed up, piece by piece, very much in the manner that one would pack up lantern slides. The panes were placed in cases and buried in specially made dug-outs. In the course of taking down these twenty-three windows, and of handling them in the way that was essential to their careful preservation, it was found that the whole of the windows were really in a very dangerous condition of decay, owing partly to the perishing of the lead, and partly to the actual condition of the glass. A critical examination was made as soon as was convenient after the termination of the war, and on taking advice they were assured by experts that unless immediate steps were taken to preserve the glass it would perish very rapidly, and the windows would be irretrievably lost. The work of restoration had, therefore, been precipitated.

In the autumn of 1921 skilled advice was again sought and leading authorities were called in, with the result that the expert committee, under whose advice the Dean and Chapter were now acting, consisted of the Provost of Eton (Mr. M. R. James), Mr. F. W. Troup, Mr. G. P. Hutchinson, Mr. Noël Heaton, and Mr. A. R. Powys—all of them recognised authorities in different departments of the subject.

What were the results of the investigations which had been made? One important fact which had come to light was that much of the lead used in the construction of the windows was of poor workmanship, and not only had it perished, but it was not strong enough for its purpose. The weight of the windows, combined possibly with the effects of the weather, had caused them to sag and crumple. In some of the chapter house windows many pieces of glass had fallen out, and it was a painful experience having to watch these windows, priceless and beautiful as they are, literally falling to pieces. A pin-prick of light was the first sign of decay; some months afterwards much more light was noticeable; and in one window which had been under observation as many as six pieces of glass had fallen out within the last two years.

With regard to the condition of the glass itself, the Dean went on to say that he had got himself into trouble with chemists for having spoken in public of the glass having contracted "something in the nature of a disease." What actually happened was that in a given piece of glass there would occur pit marks as if the glass had been pecked at by a bird. These pit marks spread one into the other: the surface flaked off and, of course, the glass at that particular spot became thinner. Such a process had been going on for hundreds of years, and the result of it had been that while there was some glass in the windows quite thick, as thick as a piece of fairly thick cardboard, other pieces were as thin as a single piece of paper; and there were still other pieces in which the nature of the glass had completely perished, so that it was of no use whatsoever. Some of it was only of the consistency of an incandescent gas mantle and could be blown to dust. The whole process could be therefore seen from a piece of perfect glass right down to a film of dust which had almost lost all cohesion. He had been told that the trouble was really due to the dreadful Yorkshire atmosphere, but he was sure that there was not a word of truth in that statement. Exactly the same kind of corrosion is found in country places in England and all over France. Mr. Noël Heaton attributed the decay to the quality of the sand which was used in the manufacture of the glass, and he (the Dean) had endeavoured to build up a theory on the strength of that view, namely, that so long as French sand was used in the manufacture of the glass these undesirable qualities were observed, but when the time came during the French wars when it was no longer possible to obtain French sand and Cornish sand was used, the defect was less apparent.

In the work of renovation, the method that had been adopted for the cleaning of the glass might be interesting to describe. The method pursued was as follows: a whole pane was put into a bath specially constructed for it and immersed in warm water. It was left in that bath for forty-eight hours. The effects were (1) to soften the lead so that it could be pressed out flat; and (2) to disintegrate the dirt. The glass was brushed over with soft brushes. When this process was complete the pane was taken out of the bath and a rubbing of it taken, every piece of glass being marked, so that the workmen might know exactly where to replace it when it had been renewed.* The pane was then taken to pieces. The old leads were peeled off, and the whole construction was ultimately built up anew in the manner of reconstructing a jig-saw puzzle. The panes were being built up in new lead work, constructed so as to be much more durable than the original, only "virgin" lead being used. It would be seen that the work entailed not only wonderful skill and delicacy, but that it would also take a very long time. The experts had expressed the view that it would be better to use some other kind of solvent in order to release the dirt and the old cement, and correspondence was still in progress on this question.

Another recommendation of the experts which was rather interesting was that the very laborious process of putting the cement under each piece of lead with a knife should be adopted instead of brushing it all over the newly-leaded glass. There were arguments both for and against this suggestion. One of the critical arguments against the brushing process at present in use was that the little pit marks in the glass got filled up with cement and had to be cleaned out, which entailed considerable labour and some amount of time. On the other hand, putting the cement under each piece of lead, when there were tens of thousands of them, was an extraordinarily slow and laborious operation. Many of the windows had not been disturbed for hundreds of years: perhaps never since they were placed in position had they been cleaned in any way. The condition of these windows was almost unimaginable. Nothing more startling could be conceived than to see one of these windows

* Careful photographs of the windows are being filed.

put back after the process of cleaning was completed. The brilliancy of the York Minster windows when replaced after treatment was amazing to those who had known the same windows before the cleaning process was started.

The Dean said that it was his own opinion that the great value of these wonderful old church windows lay in their use as decoration, and the recognition of this was influencing them in regard to the technical treatment of the glass in the preservation process. In the great east window at York there was a perfect example considered from this point of view. It was not the primary aim of the fifteenth-century artists to teach people by means of the subjects of these windows. At least if that were their object they failed signally, for no ordinary person without a good deal of study would be able to make out what the subjects were. From a decorative point of view, however, their work was perfect, and it was with this in mind that the endeavour was being made to preserve the windows. They were not attempting to *restore* the windows. He hoped that would be specially borne in mind. No effort was being made to reconstruct what was originally there. If a piece of glass were lost all that they were doing was to put a piece of plain-toned glass in its place.

With regard to the criticism that the windows which had been treated were now altogether too brilliant, and that " the mellowing effect of old age " was being destroyed, he did not think this was a reasonable view to take; he was rather inclined to think that the brilliancy was just what the old artists intended it to be. If, for instance, one possessed a painting by Vandyke so begrimed by dirt as to be almost unrecognisable, one did not talk about the " mellowing effect," but proceeded to get it cleaned as carefully as possible. This was precisely what they were attempting to do with the stained glass at York Minster. Early glass painters did not intend to rely on the mellowing effect of dirt.

DISCUSSION.

Prof. W. E. S. TURNER said he could assure Dr. Norris that if the Society of Glass Technology could do anything to assist him in the work he had in hand such assistance would be gladly given. Dr. Norris had put forward some theories, and he would like to assure him that his theories were not far wide of the truth. A good deal was already known of the way in which glass behaved with age, and that behaviour could, by certain treatment, be expedited. The Department of Glass Technology at Sheffield University had published at least a dozen papers during the last five years dealing with the decay of glass, and therefore had some knowledge of the subject. The flaking and the pitting were two separate stages of what Dr. Norris had perhaps rightly described as a disease. It was a sort of drinking diabetes. It was a slow and progressive disease in glass which could be expedited at certain temperatures. The glass took up water, in a very limited sense, in the same manner as a sponge. That water slowly reacted on the glass, producing flakes which were not of the same composition as the original glass, but something different. These flakes gradually fell away. They could be intentionally produced, and had been produced at Sheffield many times, as well as the pitting. The second theory which Dr. Norris suggested, namely, that the French sand might have had something to do with the trouble, was a possible one, although it might only be a shot in the dark. The French sand was probably purer than our own Cornish sand, which very often contained several per cent. of alumina; and this should increase the durability of the glass. The type of glass made in the thirteenth and fourteenth centuries was a lime glass, usually with about 6–8 per cent. of lime. Such a glass is somewhat absorbent of moisture. A lead glass had not, up to that period, been made. The decay which had taken place in the glass was certainly not due to the smoke of Sheffield driving slowly up to York; it was more likely to be due to the absorption of moisture, and this would have taken place just as effectively in the Cotswold Hills as in York city. The Society of Glass Technology would very much appreciate the pleasure of visiting York Minster on some future occasion, and if any suggestion could be made to Dr. Norris to assist him in the furtherance of the important work to which he was giving so much of his time and attention, the members would be delighted to be of assistance.

Dr. M. W. Travers expressed the thanks of the Society to the Dean for his interesting information with regard to what was being attempted at York. He was inclined to think that samples of the various glasses from York Minster should be chemically analysed, in order to find out the changes that were taking place in them; for, although the result of such chemical analysis would not, of course, render possible a cure, differences might be found between the glasses which had pitted badly and those which had not, and might throw some light on the composition of the sand used and its effect on the stability of the glass. There were also other questions bound up with the colours of these old glasses in connection with which the chemists might help. A good deal of work had been done on the subject, but further work might still be embarked on to advantage. The chemists, he thought, might have quite a good deal to say on the subject.

Dr. Norris said he was very interested to hear what Prof. Turner had to say in regard to the disease of glass. He would now be able to face Mr. Noël Heaton with greater confidence than he would otherwise have been able to do.

Mr. W. Butler said that as one who was born and had lived in York for half a century, he had a great love for the Minster, and had had the pleasure of seeing the windows under the guidance of experts. He understood there were some of the windows which came from Rouen in the fourteenth century.

The Dean of York replied that there was *one*, but it was not reckoned in the one hundred and nine referred to in the address.

Mr. W. Butler said he was going to suggest that close investigation of this imported window in comparison with the others might solve the problem of the difference in durability. The glass made in England was different in weathering from the glass which came from Rouen. Then with regard to the windows, the pieces of glass were full of little blisters and pits. When one considered the breezes that blew round the Minster one could scarcely wonder that the dust, etc., blown about, particularly on the north side, might bore holes in the glass. One would naturally expect some wear and tear. He thought the outer surface of the glass would become worn by the dust and by falling rain and the pits produced in the glass would hold the water, leading to further action.

Mr. T. Robertson observed that the cause of the distorted and irregular shapes often seen in stained glass windows was the action of the sun in expanding the lead calms, which were filled with cement to make the window water-tight. This cement set very hard and when contraction took place any piece of glass which had been drawn away could not get back to its original position. Hence by the repeated action with the seasonal changes of temperature the window was gradually twisted until it became very noticeable.

This was often the cause of pieces of the glass being cracked, or even broken and lost by falling out. Even so, a window was often peculiarly strong after it had gone many inches from its original flat surface; yet it was almost impossible to get it back to its original flatness, except by treatment which would necessitate the re-cementing of the whole window. This was not to be recommended; the best method was to take the window carefully to pieces and re-make it with new lead.

There were many ways of protecting windows affected by the twisting and bulging referred to, but they must remember that the lead of the very old windows was badly oxidised. Whilst it might retain sufficient strength to hold the glass in position, once it was disturbed by handling it would easily fall to pieces.

XII.—*The Production of Colourless Glass in Tank Furnaces with Particular Reference to the use of Selenium. Part I.*

By A. Cousen, B.Sc. and W. E. S. Turner, D.Sc.

(*Read at the Stourbridge Meeting, March 15th,* 1922.)

The production of colourless glass in tank furnaces several years ago in America passed out of the experimental into the commercial stage. In this country colourless glass had only been made up to three or four years ago in pot furnaces. There has, however, been a rapid development in the use and manufacture of colourless glass containers and the demands of the public have already led, and will lead in the future, to the conversion of former green glass tank furnaces into those producing colourless glass.

The success of the process has been made possible through the introduction of selenium, either in the form of elementary selenium, or as a salt such as sodium selenate or selenite. Selenium differs in its action from manganese dioxide in several ways, more particularly, however, for the reason that it functions in the presence of reducing agents, whereas manganese dioxide requires just the opposite conditions. The atmosphere of a tank furnace is, therefore, not normally very suitable for manganese dioxide, although to a limited extent it is applied. For selenium, however, tank furnace conditions are appropriate.

One of us has very frequently, during the past three years, been consulted as to the methods to be adopted in order to obtain colourless glass in a tank furnace, and the reply has been in all cases that there is no species of magic by which the result can be accomplished, the prime requisite being the use of pure materials, carefully controlled, so that the iron oxide should fall below a certain very small value. Having obtained such pure materials, they should be stored and mixed under conditions such as will prevent impurities from gaining access to them. The most important factor concerned, as will clearly be brought out in this paper, is the total amount of iron oxide present in the glass, and if this is maintained well within the limits set out, success is not difficult to attain.

To illustrate the process a little more concretely, the following batch composition is typical of most of those in use both in America and in this country, namely :—

Sand	1000 lb.
Limestone or limespar	180 to 200 lb.
Soda-ash	350 ,, 400 ,,

If the sand contains not more than 0·03 per cent. of iron oxide and the limestone not more than about 0·06 to 0·08 per cent., the amount of selenium required is usually in the neighbourhood of half an ounce per 1000 lb. of sand. There must also be added a very small amount of cobalt oxide, which may lie between one-sixth and one-eighth of the weight of the selenium, that is, between one-twelfth and one-sixteenth of an ounce.

In stating this batch composition it must clearly be understood that adjustment of the selenium and of the cobalt oxide will have to be made from time to time to suit the particular conditions. Thus it is still possible to decolorise sand which contains 0·05, 0·06, and even 0·07 per cent. of iron oxide, provided the other batch materials are reasonably pure. It may, however, be found necessary to use distinctly more selenium. Cases are known, indeed, where the amount of selenium added may exceed 2 or 3 oz. per 1000 lb. of sand. In such cases, however, a first-class colourless glass is not produced.

The question remains as to what is the limit for the amount of iron oxide present, in order that decolorising shall fall just within the points of possibility. We shall answer this more completely in the experimental section of this paper, but we may say that from a number of analyses carried out in this laboratory of commercial glassware, the upper limit may be placed in the neighbourhood of 0·1 per cent. of iron oxide. We have found the glass still to be practically colourless at 0·11 per cent., but when in excess of this value the green tinge is quite noticeable; indeed, it may just be detected in thick glass when 0·1 to 0·11 per cent. of iron oxide is present. Should an attempt be made to decolorise a glass containing considerably in excess of 0·1 per cent., the result is very unsatisfactory, the glass acquiring a muddy colour which may be either green-, yellow-, or even black-looking. It must be clearly understood that for satisfactory decolorising the total iron oxide content must not at the outside be more than 0·10 per cent., and it is clearly obvious that the glass will be so much the better the smaller the iron oxide value below the limit.

From the above statements, which are based on ordinary practice, it will be clear in the first place that very careful control is needed, and, secondly, that we have to do with very small quantities; for example, on the one hand of iron oxide, and on the other of selenium and cobalt oxide added. It is to the study of the amounts of these substances in so far as they are affected by a number of different factors that this paper and subsequent ones will be devoted. For example, one of the questions asked at the recent meeting at Leeds concerned the effect of salt-cake on the possibility of decolorising with selenium. It was stated that as a matter of practice difficulty had been found in obtaining decolorising in the presence of salt-cake. It will also be noted that in the batch referred to above no reference is made to salt-cake. Very frequently an entirely soda-ash batch has been used. In other cases where salt-cake is added the amount is very small. One of the problems which we set ourselves was to ascertain what is the effect of salt-cake.

In addition to this factor there are others, some of which we have already pursued investigations on and still others which must await solution. Thus, the relative value of selenium and of sodium selenite constituted a problem in itself. Further, the function of white arsenic, which is a frequent addition, also needs to be elucidated, and thirdly, the effect of reheating and of cooling in the annealing oven. Reference is made to these subjects in what follows.

The General Conditions of Experiment.

The experiments were carried out on a small scale, and this must be borne in mind when applying the results to practical operation in large furnaces. One of the sources of iron oxide in the finished glass arises from the corrosion of the fireclay receptacle, whether it be the tank-blocks in a tank furnace or the crucible in a pot furnace In the small pots used the area of fireclay surface exposed to the action of the glass was relatively very much greater than in the normal large tank furnace, and this must be borne in mind. Nevertheless, very definite principles are obtainable from our meltings and apply equally to the more practical operations. Indeed, in cases where we have been able to make comparison, the small scale results are in close agreement with commercial practice.

The standard batch was as follows :—

Sand (Fontainebleau)	100 parts
Soda-ash	37 ,,
Limespar	20 ,,

The iron oxide in each of these three chief batch materials was determined, with the result that the sand was found to contain 0·016 per cent., the limespar 0·05 per cent., and the soda-ash 0·01 per cent.

As a decoloriser, selenium or sodium selenite was employed. The particular form is stated in the tables given below. The unit amount of selenium was 0·003 part per 100 of sand, and multiples of this amount, namely, 1, 2, or 4 times, were used in various experiments. This unit amount, namely, 0·003, corresponds with half an ounce per 1000 lb. of sand, so that the other quantities can readily be reduced to the same basis.

Cobalt oxide was added to all the batches. At first an amount equal to one-sixth of the selenium was used, but it was found that when the content reached 0·002 part of cobalt oxide per 100 of sand, a distinct blue colour was obtained. The best results occurred when the cobalt oxide added represented 0·0005 of a part per 100 parts of sand, and this amount was adhered to throughout the series of meltings.

The time taken for the complete melting operation was three to three and a half hours. The temperature was maintained constant at a particular value, some meltings being made at 1370° to 1380°, a few at 1400°, and a series at 1440°. These tests enabled one to ascertain to some extent the effect of temperature on the colour. In all cases slabs of glass were poured from the meltings and the test-pieces were annealed in a closed muffle furnace and subsequently examined for colour and analysed for iron oxide content.

The Percentage of Iron Oxide in Glass Capable of Being Decolorised by Selenium.

In the study of this problem, not only purely soda-ash batches, but also others containing salt-cake were tested. In the latter, 1, 2, and 4 parts of the soda-ash were substituted by salt-cake, so that the four batches compared were as follows :—

	1.	2.	3.	4.
Sand	100	100	100	100
Limespar	20	20	20	20
Soda-ash	37	36	35	33
Salt-cake	—	1·35	2·7	5·4
Cobalt oxide	—	0·0005	0·0005	0·0005
Selenium or sodium selenite	—	as required	as required	as required

The data and the general results summarised in Table I were obtained when melting was carried out at 1380°.

In Table II meltings were made of a somewhat similar character but at a higher temperature, mainly at 1440°. A few further meltings at 1380° are included of glasses which were very distinctly green in colour.

In the set of glasses tabulated in Table II the depth of colour increased with the iron oxide content.

When all the results in Tables I and II are considered it is possible to state fairly accurately the limit of iron oxide content which may be neutralised by means of selenium or sodium selenite. The actual amount of iron oxide dissolved from glass to glass unfortunately differed distinctly, and it will readily be seen that the higher values, that is, the greener glasses, were those

TABLE I.

No. of sample.	Parts of decoloriser per 100 parts of sand.		Parts of salt-cake.	Per cent. of iron oxide.	Colour.
	Selenium.	Sodium selenite.			
2	0·003	—	0	0·07	Decolorised
3	0·003	—	0	0·06	,, ,,
8	0·006	—	0	0·07	Brownish-yellow
154	0·012	—	0	0·08	Deep amber
59	—	0·0065	0	0·08	Amber
68	—	0·0131	0	0·08	Deep amber
77	0·012	—	1·35	0·04	Very slightly over-decolorised
78	0·012	—	2·7	0·04	,, ,,
79	0·012	—	5·4	0·04	,, ,,
19	0·012	—	1·35	0·11	Faint green
22	0·012	—	1·35	0·08	Decolorised
53	0·012	—	1·35	0·11	Faint green
20	0·012	—	2·7	0·08	Decolorised
21	0·006	—	5·4	0·08	,, ,,
10	0·006	—	1·35	0·08	,, ,,
36	0·006	—	1·35	0·11	Very faint green
29	0·006	—	2·7	0·11	Faint green
45	0·006	—	5·4	0·10	Very faint green
58	0·006	—	5·4	0·10	,, ,,
4	0·003	—	1·35	0·11	Pale green
5	0·003	—	2·7	0·10	,, ,,
6	0·003	—	5·4	0·11	,, ,,
74	—	0·0262	5·4	0·11	Very faint green
69	—	0·0131	1·35	0·09	Decolorised
141	—	0·0131	1·35	0·06	Very slightly over-decolorised
70	—	0·0131	2·7	0·07	Decolorised
60	—	0·0065	1·35	0·10	Very faint green
61	—	0·0065	2·7	0·09	,, ,,
116	—	0·0065	2·7	0·09	Decolorised

TABLE II.

No. of sample.	Parts of decoloriser per 100 parts of sand.		Parts of salt-cake.	Temp. of melting.	Per cent. Fe_2O_3	Colour.
	Selenium.	Sodium selenite.				
31	0·006	—	0	1440°	0·08	Pale straw
65	—	0·0065	0	1440°	0·09	,, ,,
26	0·006	—	1·35	1440°	0·12	Pale green
28	0·006	—	1·35	1380°	0·14	Green
67	—	0·0065	5·4	1440°	0·14	,,
43	0·012	—	2·7	1380°	0·14	,,
42	0·006	—	2·7	1380°	0·14	,,
93	—	0·0065	5·4	1380°	0·14	,,
12	0·006	—	5·4	1380°	0·15	,,
14	0·003	—	1·35	1440°	0·15	,,
25	0·003	—	5·4	1440°	0·15	,,
73	—	0·0131	5·4	1400°	0·16	,,
66	—	0·0065	5·4	1440°	0·16	,,
27	0·006	—	5·4	1440°	0·17	,,
33	0·006	—	5·4	1440°	0·18	,,
15	0·003	—	2·7	1440°	0·22	Bright green

made at the higher temperature of 1440° and particularly those which contained salt-cake.

It will be seen that in practically all cases a glass containing up to 0·09 per cent. of iron oxide was capable of being decolorised. In some cases, indeed, over-decolorising results, such as in the case of glass No. 65, occurred.

It will further be seen that when the amount of iron oxide reached 0·10 a faint green tinge became apparent in the pieces examined. The thickness of these pieces varied between three-sixteenths and three-eighths of an inch. In the usual bottle thickness for medical bottles probably this very faint green colour would not be noticed. Undoubtedly, however, with 0·11 per cent. of iron oxide the green colour began to be apparent and, in all cases tested, as the percentage more and more exceeded 0·10, the green colour became more and more intense. We may therefore fairly put the limit of iron oxide capable of being decolorised by selenium at 0·09 per cent., with a possible further allowance of 0·01 per cent. in commercially produced glass.

The Effect of Salt-cake on the Decolorising Action of Selenium.

The results already set out in Tables I and II also quite clearly demonstrate that the addition of salt-cake has a definite effect in the decolorising action of selenium. In other words, it is easier to decolorise a batch in which soda-ash is the only source of alkali than when a proportion of salt-cake is present. No attempt has so far been made to test a batch containing salt-cake but no soda-ash; it is quite apparent that even a small proportion of salt-cake makes a difference, plainly seen, for example, when comparison is made of the glasses Nos. 154 and 77. The former was made from a soda-ash batch, the latter from a batch containing 36 parts of soda-ash to 1·35 of salt-cake. Twice as much iron oxide was present in No. 154 as in No. 77; yet, with the same amount of selenium added, the former glass was much more over-decolorised than the latter; in other words, less selenium is required to obtain colourless glass when the latter is made wholly from soda-ash than when salt-cake is present.

The analysis of the causes why the salt-cake batch should need more selenium or sodium selenite than the soda-ash batch is not perfectly easy from the data obtained. Two factors, however, appear to stand out as the most important ones in operation.

The first of these causes seems to lie in the greater corrosive action of the batches containing salt-cake as compared with those containing soda-ash only. Such comparatively greater corrosive action was not always found (compare, for example, glasses Nos. 154

and 77), but, generally speaking, the higher percentages of iron oxide were to be found associated with the salt-cake glasses. Examination of Table II furnishes clear evidence to this end. And if salt-cake generally brings about an increase of iron oxide content, more selenium will be needed for decolorising.

This increase in the amount of selenium needed when salt-cake is present seems to be due to another reason besides its action in increasing the iron oxide content. Attention has already been directed to the fact that when salt-cake is present, as in glasses Nos. 77, 78, and 79, the presence of 4 units of selenium was not so excessive as in the case of glass No. 154, which contained twice as much iron oxide. Moreover, it will be noticed that in glass No. 8, made without salt-cake, 2 units only of selenium produced a brownish-yellow colour when 0·07 per cent. of iron oxide was present. There must clearly be some action between the salt-cake and the selenium such as does not occur between sodium carbonate and selenium.

In this connection it is interesting to note that in dilute acid solution at 100°, colourless sodium selenite reacts with sulphur dioxide to give selenium itself, the reaction being represented by the equation :

$$Na_2SeO_3 + 2SO_2 + H_2O \longrightarrow Se + Na_2SO_4 + H_2SO_4.$$

The phenomenon of loss of decolorising power when salt-cake is present suggests that at higher temperatures, such as exist in the glass furnace, this reaction is reversed and selenium oxidised by the salt-cake.

In order to test the point qualitatively, pure sodium sulphate was melted in a platinum crucible in an atmosphere of carbon dioxide, and selenium dropped on to the surface of the liquid. The great difference between the temperature of vaporisation of selenium (680°) and the melting temperature of salt-cake (885°) rendered quantitative observations by this method useless, but distinct qualitative results were obtained. It was observed that, as the selenium touched the surface of the salt-cake, the layer in contact with the molten salt instantaneously turned white and then sank and dissolved in the liquid, whilst the bulk of the selenium rapidly vaporised. After several additions, the salt-cake was cooled, dissolved in water, and filtered (to ensure that no elementary selenium was present). The clear, colourless solution was boiled, hydrochloric acid added, and a current of sulphur dioxide passed through it. In all cases the solution became pink and several milligrams of selenium were precipitated.

Whether 0·5 or 5 grams of salt-cake was used, almost the same amount of precipitated selenium was obtained. On filtering, boiling down with hydrochloric acid, and again passing sulphur dioxide, no further precipitation of selenium occurred. This proves that the action between salt-cake and selenium actually occurs at high temperatures with the production of sodium selenite, a colourless salt, but with no formation of sodium selenate. When the two substances are in solution in the molten glass it is probable that the action will much more readily occur than when the substances are merely brought together in a platinum crucible.

In the production of the glass, therefore, it seems evident that the loss of decolorising power of the selenium, observed when even a small amount of salt-cake is present, is due, not only to the higher iron oxide content usually arising owing to corrosion of the fireclay, but also to the production of colourless selenite.

The Comparative Decolorising Action of Selenium and Sodium Selenite.

Both elementary selenium, either red or black, and sodium selenite are used in commercial work for decolorising purposes, as well as for the production of ruby red glasses.

The disadvantage which has usually been associated with the elementary selenium is that it vaporises at a comparatively low temperature, resulting always in a loss of the material. Such loss due to volatilisation was certainly detected in our experiments by the smell of selenium when the batch was charged into the hot pots.

In order to obtain some definite data by which to compare the efficiency of selenium and sodium selenite, comparative meltings were carried out with the standard batch already set out, containing soda-ash only as the source of alkali and no salt-cake.

Since sodium selenite contains 45·7 per cent. of selenium, the amount of selenite equivalent to 0·003 part of selenium is 0·0065, and this quantity we may also refer to as one unit (that is, the equivalent of ½ oz. per 1,000 lb. of sand). The amount of cobalt oxide present was 0·0005 part and the temperature of melting 1380°. Table III states the results.

Our experience showed that, with selenium, decolorising was readily obtained by one unit (that is, by 0·0003 part or ½ oz. per 1000 lb. of sand). This result was obtained when the glass contained 0·07 per cent. of iron oxide and is in fairly close accord with results obtained in large tank furnaces. Two units of selenium (0·006 part or 1 oz. per 1000 lb. of sand) when the iron oxide is about 0·07 per cent., are, from our results, clearly excessive, whilst 4 units (0·012 part) yield an amber colour. We may remark that

TABLE III.

	Wt. of decoloriser per 100 parts of sand.		
No. of glass.	Selenium.	Sodium selenite.	Resulting colour.
154	0·012	—	Deep amber
8	0·006	—	Brownish-yellow
9	0·006	—	,, ,,
151	0·006	—	Pale straw
2	0·003	—	Decolorised
3	0·003	—	,, ,,
68	—	0·0131	Very deep amber
59	—	0·0065	Deep amber
125	—	0·0033	,, ,,
148	—	0·0033	,, ,,
126	—	0·0017	Fairly deep amber
149	—	0·0017	,, ,,
127	—	0·0008	,, ,,
150	—	0·0008	,, ,,
156	—	0·0004	Amber
159	—	0·0002	Faint straw
162	—	0·0002	Faint green

some manufacturers have, in their early attempts to produce colourless glass, obtained amber tints. The reason, in the cases we have been called to investigate, has been the use of excessive amounts of selenium.

In regard to sodium selenite, there is no doubt at all that, under the conditions of experiment, it was much more powerful as a decoloriser than was selenium. Indeed, it has been found somewhat difficult to add a *small enough* amount to obtain decolorising. In two experiments it will be noted that with 0·0002 part the residual colour was a faint green in the one case, in the other a faint straw; that is to say, the sodium selenite required for decolorising a wholly soda-ash batch was in the neighbourhood of 0·0002 part, or only about 1/64 oz. per 1000 lb. of sand. Any quantity in excess produced an amber colour.

Such a result is remarkable, and it is difficult to associate the much smaller efficiency of the selenium with a wholesale loss by volatilisation. What the volatilisation loss is we cannot conjecture, but we propose to carry out experiments whereby to test the amount.

Nor can we at the present time clearly understand, if selenium loses its efficiency when salt-cake is present through conversion to selenite, as we have already suggested, why sodium selenite itself in a soda-ash batch should be so remarkably efficient. The two results at first sight appear contradictory. How far the efficiency of either is influenced by a reducing atmosphere or by the addition of white arsenic we have yet to ascertain, and experiments are proceeding on these lines.

Finally, it may be desirable to point out again that this apparently great discrepancy in decolorising power between selenium and sodium selenite does not hold good when the batch contains salt-cake.

The Possibility of Colour Change During Annealing or Re-annealing.

It is the usual practice in decolorising with manganese dioxide to arrange that the glass, when worked from the pot, shall be slightly high in colour, that is, shall show a faint pink tint, as the subsequent annealing always causes slight reduction. As the result, an article which goes into the annealing furnace with a slight pink tinge is usually found to be better decolorised than one which is placed in the lehr apparently already decolorised.

It seemed of interest, especially in view of several statements that selenium glass also shows colour changes, to make a number of tests on the point.

In the tests we have made the sample pieces were already cold and the study has been rather of re-annealing than of the ordinary slow cooling down process which commercial articles mainly receive.

The series of tests was carried out in an electrically heated tube furnace. Selected pieces with a known colour were placed in the furnace and heated at a series of different temperatures, namely, 500°, 525°, 550°, 575°, 600°, and 625°, three different periods of heating being applied, namely, one, three, and six hours. The colours of the samples used are stated in Table IV.

TABLE IV.

No.	Initial colour.	No.	Initial colour.
15	Bright green	36	Very faint green
14	Green	60	,, ,,
12	,,	2	Decolorised
42	,,	10	,, ,,
4	Pale green	22	,, ,,
5	,, ,,	13	Pale straw
6	,, ,,	31	,, ,,
26	,, ,,	8	Brownish-yellow
29	Faint green	59	Amber

At each particular temperature the samples were examined at the end of each of the periods stated.

No change was observed in the first sixteen samples at any temperature or at the end of either one, three, or six hours' heating. The last two glasses, however, both became perceptibly deeper in tint even after one hour at 525°, and the increase of colour reached a maximum with three hours' heating. With increase of temperature to 550°, the intensity of colour produced also increased. Above this point, the colour change on heating again diminished until, at 625°, no difference between the initial and final colours could be observed. From our experiments, it is evident that no colour change takes place in a selenium-containing glass unless a fairly deep selenium tint is initially present. In such case the maximum deepening effect occurred at about 550°. The decolorised sample of glass was found to undergo no change.

In view of the fact that, in practice, ruby coloured selenium glasses are usually produced by reheating the colourless or straw-coloured glass, our results are perhaps a little surprising, although the development of a deeper colour in the already coloured samples is in accord with practical experience. But it is to be noted that 37 the conditions inside an electrically heated tube furnace are slightly different from those inside the ordinary lehr, where the atmosphere is most likely reducing in character. It is possible, therefore, that under such conditions colour changes would take place such as we have not found. We propose to make some further tests under reducing conditions. Moreover, since the glasses had already been annealed and our heating process was really the process of re-annealing, we propose to carry out observations in which the hot samples of glass after being poured are cooled down slowly at different temperatures such as would obtain in the ordinary lehr.

It may be pointed out that the conditions inside the electric tube furnace are very much those which would exist inside the muffle lehr now fairly commonly used.

Summary.

(1) A large number of small scale meltings have been carried out to determine the relative effect of selenium and sodium selenite as decolorisers both in salt-cake batches and in others free from salt-cake. The meltings were carried out mainly at 1380° but some also at 1440°.

(2) The maximum percentage of iron oxide in the glass which it is found possible to decolorise either by selenium or by sodium selenite is 0·09. A further allowance of possibly 0·01 per cent. may be made in commercially produced glass, but the smaller the iron oxide content below 0·09 the better the glass in appearance.

(3) The presence of salt-cake even in only very small amounts in the batch calls for an increased amount of selenium for decolorising purposes.

(4) The ordinary soft bottle glass batch containing a small proportion of salt-cake appears to be more corrosive of fireclay material than the corresponding soda-ash batch. Consequently the amount of iron oxide present in the glass is increased and decolorising is less easy.

(5) There is evidence that elementary selenium reacts with salt-cake at high temperature and is to some extent converted into sodium selenite.

(6) In batches containing soda-ash only, sodium selenite appears to be very much more effective in decolorising action than elementary selenium. Whereas ½ oz. of selenium per 1000 lb. of sand is required with the ordinary soft bottle glass batch, an amount only of 1/64 oz. of sodium selenite is found to be sufficient under the conditions of our experiments.

(7) When selenium-containing glasses are reheated it appears that colour changes only take place in those glasses which have been over-decolorised; that is to say, in which there is a distinct selenium tint. The effect of reheating is to deepen the tint, and this change occurs perceptibly at a temperature of 525° and still more effectively at 550°. At still higher or at lower temperatures the colour change is not distinctly observed.

Further experiments are proceeding to ascertain the relative value of selenium and of sodium selenite as decolorisers; to test the influence of reducing agents, including white arsenic, and to study further the effect of annealing.

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DISCUSSION.

MR. E. A. COAD-PRYOR said that the question which Prof. Turner had raised was very important, and he would like to ask him first of all how much arsenic was introduced into the batch in addition to the selenium. It was scarcely clear to him that Prof. Turner's explanation could be the whole story, because one would rather expect the effect of the salt-cake on the selenium to be proportional to the amount of salt-cake that was added. If the salt-cake were doubled, he would expect to find that the selenium was destroyed, or at least rendered inert. The most exciting part about the experiments appeared to be that the selenium was rather fugitive in the lehrs in the same way that manganese was. But it was fugitive in rather a tricky way. There was a critical temperature around which the colour went pink, and below which it went green. He was not prepared to say just what that temperature was, but it was surprisingly low, and it might be possible, by an ingenious manipulation of the lehrs, to prepare that colour favourably. In that connection it would be extremely interesting to know whether Prof. Turner had noticed that the rate at which the colour went up or down varied with the salt-cake and also with the arsenic.

He (the speaker) was inclined to think that it did, but it would require further experiment. Comparing the results of work on a tank with small scale melts in the laboratory, he had not found so much divergence as Prof. Turner would lead one to expect. With regard to the difference of the behaviour of a glass which was cooled in the ordinary way—that is, the article after being made was passed through the lehrs—as compared with a glass which was cooled quickly in a small melt and reheated, he had found the results, as a rule, fairly parallel. Further information with regard to the influence of the salt-cake on the fugitiveness of the colour would, he thought, be of extreme value.

Mr. W. P. Johnson said he would like to ask Prof. Turner if he did not think there might be another explanation for the large amount of selenium that was required as the salt-cake increased, namely, the fact that salt-cake was a very crude product, and therefore included a large amount of iron oxide in the salt-cake itself, as well as bringing in iron oxide along with the reducing agent which was added in order to reduce the salt-cake. If Prof. Turner were to make some tests concerning the amount of iron oxide in the salt-cake itself the matter might probably be cleared up altogether.

Mr. W. J. Rees said there was probably another cause of the increase in the colour of the salt-cake batches. It might be due, not to iron dissolved from the pot, but rather to the alumina dissolved from the pot. A very common source of colour in salt-cake batches was due, not primarily to the iron compounds, but to the formation of alumino-sulpho-silicates, somewhat analogous in composition to ultramarines. He would suggest that this was a possible adjunct to the deepening of the colour of the glass rather than the iron. It would be interesting to know if there were any information available from the tests which had been carried out as to the influence of furnace atmosphere on the behaviour of the selenium. The question as to whether an atmosphere was oxidising or reducing very often had a definite influence on a given problem. It would be very interesting, therefore, to know whether any information bearing on this point had been elicited from the experiments.

Mr. A. Cousen, in reply to the questions asked, said he would like to point out that white arsenic was not added to any of the batches. An endeavour had been made to maintain the batch as simple as possible in composition, so as to make it easy to trace the effect of the different factors. In regard to the salt-cake, it was a very pure sample, containing little more than a trace of iron oxide. All the other materials were of good quality. The glasses had not been analysed for alumina content, so that a precise answer to Mr. Rees's question was not possible. When the iron oxide in the glass was high, the colour was found to be bluish-green. Whether or not the alumina affected this colour he could not say. In regard to the greater amount of selenium needed for decolorising salt-cake-containing batches, the amount did not increase in proportion to the increase in salt-cake; and only a very little more selenium was needed for the batch containing 5·4 parts of salt-cake as compared with that containing 2·7 parts. The greatest difference was observed between the wholly soda-ash batch and the one with a small amount of salt-cake. Various other points had to be considered yet, but the investigations were being continued.

Prof. Turner said that Mr. Cousen had replied to most of the questions asked. He would now merely observe that they had at Sheffield conducted other investigations which would be able to solve the problem of the bluish-green colour in glass. Of this more would be reported at a later date. In regard to Mr. Johnson's remark as to impure salt-cake being the cause of the greatly increased selenium required to decolorise the salt-cake-containing batches, the suggestion was quite untenable. A little reflection would show that, in view of the small amounts of salt-cake added, it would have to be a very poor sample indeed to add any noticeable amount of iron oxide to the glass. As Mr. Cousen had pointed out, the salt-cake used contained practically no iron oxide.

XIII.—*A Critical Review of the Provisional Specifications for Glass Refractory Materials.*

By W. J. Rees, B.Sc.Tech., F.I.C.

(*Read at the Stourbridge Meeting, March* 15*th*, 1922.)

About three years ago, the Provisional Specifications were prepared by a Committee of this Society which had the benefit of consultation with representative manufacturers of refractory materials for the glass industry nominated by the Employers' National Council for the Clay Industries.

These specifications, it was hoped, would tend towards standardisation and uniformity in the production and use of the refractory materials dealt with.

It was pointed out at the time that whilst the requirements of the glass industry, in the matter of temperature, were not so drastic as those imposed by the steel industry, at the same time greater chemical resistivity was necessary, seeing that the whole of the interior of the pot in a pot furnace, or the entire internal surface of the tank-blocks in a tank furnace, is subjected to the continuous action of a molten charge of great chemical activity. The provisional specifications referred to had, therefore, been prepared based upon a combination of existing scientific data with the best practical experience, and it was hoped, in view of the fact that failures due to unsatisfactory refractories were sufficiently numerous, that all manufacturers of refractories for use in connection with the glass industry would take such steps as would enable them to comply with the specifications framed, which, although admittedly somewhat severe, seemed to be necessary if Great Britain was to keep pace with the progress of an important and rapidly reviving industry, namely, the production of glassware.

Astonishingly small use has, up to the present, been made of these specifications either by the refractory materials manufacturers or by the glass manufacturers, and it is pertinent to inquire why this is so. Are they adequate? and if not, in what direction should they be amended? Possibly the neglect of them is due to a recognition of the fact that, at best, the provisional specifications were bound to be tentative, and a great deal of data bearing upon the points at issue had yet to be collected before really definite standard specifications could be prepared which would be acceptable and useful both to the users and the makers of glasshouse refractories. It was true that some progress had been made in the collection of new data and the correlation of this with the older work, but much yet remained to be done. In spite of this, however, existing knowledge would appear to be sufficient to warrant the recommendation of the preliminary specifications as a guide to the general directions in which both users and manufacturers of glasshouse refractory materials should move.

It is desirable to emphasise that the "Recommendations and Suggestions" in Section III were only intended as such, and not as an integral part of the specifications. Misconceptions have possibly arisen on this point, but it should be quite clear that whatever specifications are adopted, manufacturers may adopt any method for the production of materials to comply with them.

Silica Bricks and Cement.

[Section II. 2 of Provisional Specifications.]

It will be generally agreed that the proposed specification for silica bricks and cement is, in the main, a satisfactory one. It has been definitely established that silica bricks and blocks which have been made to comply with the specification have given excellent results in practice. More use has been made of this specification than of any of the others and there have been outstanding cases in which the bricks and blocks so specified have given exceptionally good results under severe conditions of furnace practice—in such positions, for instance, as the pillars of certain types of high temperature pot furnaces.

It is possible that recent developments in our knowledge of the behaviour of silica and silica refractory materials may lead to a further increase in the usefulness of the specification. Possibly some figure for the maximum true specific gravity of the bricks might be included with advantage, and indications of the limits of apparent specific gravity which bricks should have would be of service in many cases. It has been found during the last year or two in America, in Germany, and to some extent also in Great Britain and France, that for certain classes of work a silica brick or block should not have a higher true specific gravity (that is, a higher density when tested as powder) than 2·35. Owing to the effect of variations in the proportion of lime or other bonding ingredient present in the brick, the powder density is not an absolutely definite indication of the extent of conversion of the quartz; but with all normal types of brick a powder density of 2·35 would indicate a fairly complete conversion of the original quartz into tridymite or cristobalite in the brick; certainly not more than 20 per cent. fo unconverted quartz would be left in such a brick.

For bricks which are to be used in such positions as furnace pillars, it might be advantageous to insert a clause in the specifications bearing on this point. For silica bricks intended for the crowns of furnaces, it is not by any means certain that such a stipulation is necessary or even desirable. In such cases, it does not appear to be essential that the conversion of the quartz should be so nearly complete; indeed, it is quite likely that in bricks which are subjected to the corrosive action of furnace dusts, the actual density concentration of the silica, whether it be in the form of quartz, tridymite, or cristobalite, is the important factor. In furnace design, provision is almost invariably made for accommodating volume changes in the crown. It must be pointed out, however, that where the proportion of unconverted quartz is high, the expansion of the bricks may cause such a considerable rise in the crown as would materially alter the conditions of combustion in the furnace.

It might, therefore, at some time in the future be necessary to divide the specification into two parts; one referring to bricks where a maximum quartz conversion is essential and one to bricks where it is not so essential.

The mechanical strength of silica bricks is obviously of considerable importance in situations in furnaces where loads have to be caried. The American Ceramic Society, which has also been considering specifications for glassworks' refractories, has suggested that the effective modulus of rupture of silica bricks could be easily measured, and that a standard 9-inch brick, supported on knife edges with a 6-inch span, should have an effective modulus of rupture of not less than 500 lb. per square inch. It is undesirable to complicate a specification unduly, but there is no doubt that the mechanical strength of silica bricks does vary very considerably. It varies both with the actual grading of the brick and the efficiency of its burning, although perhaps more with the former than with the latter. A well-graded brick of uniform texture has, almost invariably, a greater mechanical strength than a poorly-graded brick of uneven texture.

An important point which is often not sufficiently appreciated is the method of storage of silica refractories. It will perhaps be well known to many users who have had occasion to store silica bricks for some time that the bricks frequently decreased in mechanical strength after a few months' storage. Sometimes only a few weeks' storage is sufficient to cause an appreciable loss of strength. The cause of that loss of mechanical strength has been the subject of an investigation which the author has been engaged on during the last few months and the conclusion drawn is that such decrease in strength is actually due to a partial breakdown of the lime–silicate bond. Exposure to a moist atmosphere, and more particularly exposure to rain, causes a partial decomposition of the lime–silicate, or the alumina–lime–silicate, bond and thus very considerably diminishes the mechanical strength of the bricks. It is desirable, therefore, that silica refractories should be stored in a dry place.

Specifications for silica bricks for use in regenerator chambers and for the building of recuperators may also be desirable. For high temperature regenerative furnaces, much better results are being obtained with the regenerators packed with silica instead of with firebricks. This was probably because the silica brick is mechanically stronger at high temperatures and resists better the fluxing action of any furnace dust which is carried over. For high temperature regenerators, such as those, for instance, in steel melting furnaces, where regenerator temperatures of 1300—1350° are attained, silica brick fillings have given decidedly better results than firebrick. Such factors as the higher thermal conductivity, the heat capacity, and the usually greater porosity of the silica brick are connected with the favourable results obtained. The best thickness of brick for the most efficient heat interchange must be ascertained and specified. The use of bricks of a greater thickness than 2 to 2½ inches is almost certainly inefficient.

An important clause in the specification is the one dealing with variations of measurement. It is, at times, a bone of contention between the makers and the users of silica refractories, but a limit of plus or minus 2 per cent. should give the maker ample latitude; and with efficient manufacture there should be no need, even with large blocks, to concede a greater latitude.

Tank-Blocks.

[Section II. 1 of Specifications.]

The quality of tank blocks is at the present time a matter of such very considerable concern to glass manufacturers that it appears desirable to inquire if the troubles experienced are entirely due to blocks of low quality or, at times, due also to causes which are under the control of the glass manufacturer. An adequate knowledge of the conditions which blocks must withstand in modern glass-tank practice is an essential preliminary to the preparation of a revised specification.

In many cases, higher temperatures are being employed for the melting of glass in tanks than was common practice a few years ago. The extended use of automatic machines has rendered necessary a glass with different physical properties from the former common type, and this, in conjunction with the higher melting temperatures, calls for a much higher service from the tank-blocks. It is necessary to examine very closely all the conditions associated with failures of tank blocks in order to ascertain whether the failure is due to the unsatisfactory quality of the blocks or, at least in part, to contributory causes. In several instances within the experience of the author improper treatment of the tank blocks has seriously militated against their satisfactory service.

There is a large field of work which is still to a great extent unexplored as to the precise action of various types of glass batches on the fireclay blocks used for lining the tanks. With alterations in the composition of the glass batch there will naturally be some alteration in the viscosity of the layer of glass that comes into immediate contact with the tank blocks. Is such alteration going to affect to any marked extent the life of the fireclay block? Instances have been noted where comparatively slight alterations to a glass batch have resulted in a decided retardation of the rate of corrosion of tank-blocks. Unbalanced glass batches may be a possible accessory cause of excessive corrosion of tank-blocks, and this factor should receive the serious consideration of the glass manufacturers. The author is not for one moment suggesting that tank-blocks are as good as they might well be, but if real progress is to result all the conditions attending excessive corrosion must be carefully investigated.

It is desirable, when tank blocks are first put into service, that the furnace should be raised to a high temperature before any glass or glass-batch is filled on. It has been a common practice in the past to fill a cold tank with cullet and then proceed to melt the cullet. Now during the early stages of the melting the tank block is in its most porous condition and readily absorbs the molten glass. The absorption of molten glass by a tank-block is a frequent precursor of trouble; for interaction between glass and fireclay will occur within the block at temperatures below the melting point of the glass. Prof. J. W. Cobb* has shown that interaction between lime and silica, for instance, takes place at temperatures so low as 700—800°. Reactions of this type, when occurring within the pores of the tank-block, may cause very serious changes in its behaviour; the coefficient of expansion of that portion of the block will be changed with the probability of the spalling away of the face of the block and a consequent further increase in the rate of corrosion.

A good deal of experimental work has been conducted during recent years in the direction of specially coating tank-blocks in order to obtain a resistant face. In many cases, the coefficient of expansion of the coating has differed from that of the block and, on heating, differential strains were set up which resulted in a peeling off of the prepared face. Some interesting experiments have been made lately with the object of preparing a deeper-seated " coating." Attempts have been made to force by pressure a coating material to the depth of an inch or so into the structure of the tank block and so to ensure a resistant face on the block of considerably lower porosity than the rest of the block. These experiments are being continued, and it is hoped in due course to prepare blocks for testing under works conditions.

The two most important factors influencing the durability of a tank-block are, in the author's opinion, its porosity and its uniformity of texture. Probably a low porosity is more important in the majority of cases in modern tank practice than the uniformity of texture, although this latter factor has a considerable bearing on the uniform wear of the blocks. The extent of burning of the grog, the grading of the grog, the angularity of the fragments of the grog as well as the heat-treatment of the block itself, are other factors having a great influence on the life of the block. That it is possible

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* *J. Soc. Chem. Ind.* 1910, **29**, 335.

18L'

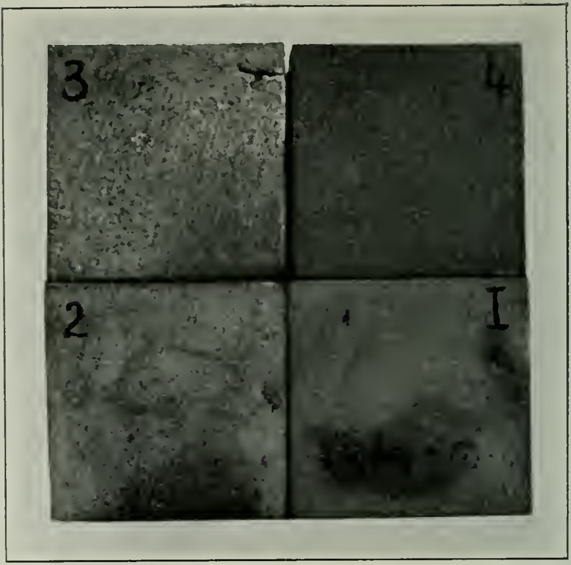

FIG. 1.

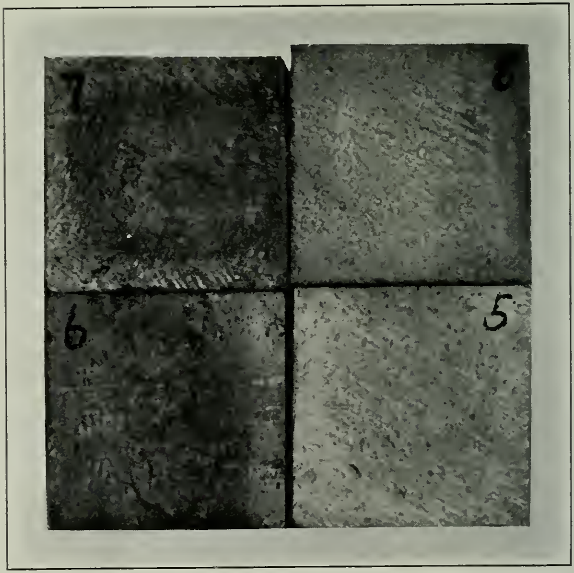

FIG. 2.

[*To face Trans.*, *p.* 187.

to make high quality blocks from British clays is indicated by an examination which the author has made of deliveries of tank-blocks from eight different manufacturers. For test purposes, 6 inch cubes were cut from these blocks and the very decided variations in texture are shown in the photographs in Figs. 1 and 2. In some of the samples there are cavities and cracks as well as other undesirable features, but two of the samples (Nos. 4 and 8) are of low porosity and of uniform texture. Both these blocks gave excellent service and one of them had a life of eighteen months in the melting end of a tank furnace melting a salt-cake batch.

The data obtained in testing these samples are as follows :

		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Volume-Porosity		27%	25%	27%	21%	26%	29%	27%	19%
After-contraction		1·8%	2·4%	1·8%	1·4%	2·0%	2·2%	2·0%	0·8%
Refractoriness	Cone	29	27	29	28	27	27	27	29

It has been suggested that it is not possible to make blocks which would comply with the provisional specification and that, if it were, there is no certainty that they would give results in practice; but the structure and behaviour in service of samples Nos. 4 and 8 afford definite evidence that such is not the case.

In order to secure uniform solubility of tank-blocks there are one or two factors to which attention should be directed. First of all, there is the desirability of having the grog of the same composition as the rest of the block; or if not of the same composition, of the same relative solubility in a glass batch. In order to secure a uniform rate of solution (that is, a uniform rate of attack), the selection and grading of the grog are matters of major importance. Much more information is required as to the solubility of our available clays in various types of glass. There are considerable differences in the rate at which various types of burnt fireclay, and of the same fireclay burnt at different temperatures, dissolve in the same glass, and these differences are accentuated with variations in the composition of the glass. Some of our fireclays, such, for instance, as some of the Dorsetshire and Devonshire clays, dissolve in glass much more readily and uniformly than does, say, a typical Stourbridge clay or some of the other coal measure fireclays which might be cited. An instance which will be well known to many users is the comparatively easy solubility of the Grossalmerode clay in glass, and it would be useful to correlate this solubility factor of the Grossalmerode clay with its wide use in Germany for the manufacture of glassworks refractories.

It is essential that a fireclay tank-block should be well burnt, and the limits which are imposed in the provisional specification are such as every manufacturer of tank-blocks should be able to work to.

The porosities which are specified are perhaps rather on the severe side. For instance, for flux-line blocks a volume porosity of not more than 18 per cent. is cited and that is possibly a rather low porosity for the manufacturer of refractories to reach; but it has actually been attained with good results, and it should therefore be done again, although it is, of course, not an easy matter and requires the utmost care and control in the manufacturing operations.

The 23 to 25 per cent. porosity cited for replacement flux-line blocks and the bottom side-blocks is easily attainable, but it is possible that, in any revision of the specification, it might be desirable to give the manufacturer a little greater latitude than 18 per cent. porosity for the flux-line blocks.

At the same time, however, it must be emphasised that a block with 18 per cent. porosity (the other physical and the chemical properties being equal) would yield a better result than a block with 20 per cent. (or higher) porosity. The porosity is, in many cases, the determining factor in the behaviour of a tank-block.

It is perhaps likely that many users do not properly realise the difficulties that the maker of refractory materials has frequently to encounter. The author certainly has realised them more during the last year or two than ever previously. Since he has had access to a great many works manufacturing refractory materials and has seen for himself the variations which are encountered in the raw materials mined or quarried, he has nothing but admiration for the degree of uniformity of product which many of the manufacturers attain.

From time to time, complaints of comparatively small variations from specified sizes are heard. Precise adherence to size is, of course, much to be desired, but extremely difficult of commercial attainment, and it is possible that the amount of work and trouble that tank-block or firebrick manufacturers go to in order to secure uniformity of raw material batches (and of their subsequent heat treatment) is not adequately realised. Examination of many clay seams reveals not only variations in the composition of the clay from place to place in the seam, but frequently from yard to yard, and these variations have to be watched constantly and allowed for by the manufacturer.

The physical and chemical changes which accompany the weathering of clays need further investigation, particularly with regard to the effect on the behaviour of the burned clays in use. Difficulties in connection with the use of fireclay feeding devices in automatic glass-making machines, for instance, are still common and need investigation. The author has recently conducted some experimental work as to the resistance offered by certain types of burned clay to sudden changes of temperature, and some of the results indicate that unweathered clays are more suitable than weathered clays for the particular purpose. The explanation of this difference in behaviour is not yet apparent, but probably there are definite changes in the chemical structure of the clay during weathering and these changes influence its physical properties.

It is noteworthy that unweathered clays appear to be more suitable than weathered clays for the production of ladle bricks for the steel industry, and it is possible that the same effect might be applicable in the production of refractory goods such as spouts and needles employed in automatic glass-feeding devices.

The laboratory-testing of the probable durability of tank-blocks —apart from the measurement of definite physical properties—is by no means simple, and there is at present no test known to the author which gives indications capable always of collation with large-scale trials of the same materials. The manufacturing-scale trial is, of course, the only really adequate test; but the accumulation of data such as are asked for in the provisional specification together with those obtained by tests such as those which will now be referred to should enable the manufacturer or user to reject really unsuitable material.

Drilling a large hole in the block, melting glass-batch in it (at working temperature) for a day or two and then, by breaking the cooled block across the hole, observing the corrosion or penetration of the glass is not really satisfactory because in making the hole the "skin" of the block is destroyed. The corrosion-retarding influence of this "skin" is not always so pronounced as is often suggested; but it is perhaps better to cement a crucible, from which the bottom has been removed, on to the face of the block and fill this with the glass batch—repeated filling and discharging is, of course, necessary. One of the American manufacturers of tank-blocks maintains a very small size tank furnace in which blocks are tested, and the provision of such a furnace in this country would greatly facilitate investigations on this type of refractory article.

The actual immersion of blocks or large samples (such as 6-inch or 9-inch cubes) in molten glass in a tank for a week or two provides information of value. The conditions of this test are severe, as the whole of the block (instead of one face only) is at the working temperature and exposed to the molten glass, but test blocks which give good or bad results generally have a corresponding behaviour in practice. The author has experienced one or two cases where blocks which have not given a good result in this test have had a fairly good life in the tank-wall; but in all the cases observed, blocks which have given a good result in the test have had a good life in the tank furnace itself. A danger in this test is the production of " stony " metal from the disintegration of poor samples.

Tank furnace experience leads to one very definite conclusion, which is that the resistance tank-blocks offer to the corrosive influences of the melting of the glass and the friction of the moving glass is of greater import than their actual refractoriness. The ideal tank-block would perhaps combine high refractoriness with high resistance to corrosion, but in the absence of this ideal it will probably pay to sacrifice a little in refractoriness in order to obtain such physical properties as low porosity which promote resistance to corrosion.

The provisional specification for tank-blocks may not, as it stands at present, be a completely satisfactory one, but a careful re-examination of it in the light of the behaviour of blocks which do, or do not, conform to it suggests that it provides a fairly sound basis on which to build.

Discussion of the influence of various external cooling devices on the durability of tank furnace walls, etc., is not within the scope of this paper, but the advantages obtained should not be left out of the consideration of glass manufacturers.

Pot Clays.

[Section II. 3 of Provisional Specifications.]

In this portion of the specification we are on even more debatable ground than in the case of tank-blocks and silica bricks. The conditions of use of glasshouse pots are so variable both in regard to the temperatures to which they are exposed and in the type of glass made, that it is improbable that a single specification will satisfactorily meet all cases.

Much discussion has taken place as to the relative merits of siliceous and aluminous clays for pot-making, but the factors other than the chemical composition of the clay which affect the durability of the pot may obscure the real issue. Definite information as to the production of saleable glass from pots made from various types of clay under the same conditions of founding and working would be of great value. Two important properties of aluminous clays must receive consideration in connection with their use for pot-making. First, their great (and often continuing) contraction at high temperatures, and, secondly, their low mechanical strength at high temperatures. This latter factor will, especially with heavy glasses, cause a bulging of the pot wall and possibly an actual collapse of the pot. Siliceous clays have a much smaller contraction than aluminous clays, and pots made from them have a greater mechanical strength at high temperatures. So much is this the case that pots, such as plate-glass pots, which are handled while at a high temperature, are frequently made from admixtures of high-silica sand with fireclay in order to give them the necessary mechanical strength.

With aluminous pots there is a tendency towards a larger proportion of " stringy " or " wreathy " metal as the difference in viscosity between the layer of glass in contact with (and interacting with) the pot wall, and the rest of the glass is greater than is the case with siliceous clay pots. Under normal glass-making conditions very good results are obtained with pots made from fireclay containing about 70 per cent. of silica but much, of course, depends on the actual manufacture and treatment of the pots. Good pots may be easily ruined in the drying room and pot arch. In this connection the siliceous-clay pots are, on the whole, perhaps, less sensitive than the aluminous ones.

The maturing of pot clay and the drying of pots are two subjects on which extended investigation is desirable. The use of drying chambers of the controlled humidity type and the determination of the quickest rate of safe drying for various thicknesses of pots are two subjects of vital importance. Investigation of the actual mechanism of the drying of clay is necessary before the safe drying of either pots or tank-blocks can be expedited.

The lining of pots with materials which either alone, or by interaction with the clay, produce a more resistant face on the pot has been the subject of a good deal of experimental work during the last few years. Much more remains to be done before a definite pronouncement as to the desirablility or otherwise of this method of pot treatment can be made. Here, again, the really vital information is the total production of saleable glass from the pot during its life in the furnace.

Information is also required as to the relative thermal conductivities at glass-founding temperatures of the various types of siliceous and aluminous clays.

The provisional specification for pot clays has received a good deal of criticism, and not all of it has been constructive criticism which could be utilised in a revision of the specification. The author, in stepping in where angels have feared to tread, would again emphasise the need for much more experimental work under carefully controlled conditions in order to obtain the necessary additional data for the preparation of a definite or precise specification. This precise specification may only be reached by a series of steps, and it will be far from disadvantageous if this provisional specification is immediately reconsidered in the light of information and data which have become available since its issue three years ago.

It is probably undesirable to specify that a pot clay mixture shall consist of at least three portions (*a*) bind clay, (*b*) base clay, (*c*) grog. It is not yet by any means certain that mixtures of these two types of clay and grog are the most satisfactory means of making a pot clay, but even if it were, it would be better to leave the application of this information to the pot clay manufacturer and to specify only the physical and chemical properties which the pot clay should possess.

It may be desirable to amplify the clause relating to the fusion test and to specify a minimum normal refractoriness and a minimum refractoriness under a load of, say, 25 lb. per square inch. The grading of the clay and grog will affect the behaviour of the mixture under these tests, and it may be necessary to indicate the maximum size of grog permissible when the available data justify it.

The presence of much more than 2 per cent. of iron oxide is undesirable whether it be segregated or uniformly disseminated; it may perhaps favour uneven corrosion if segregated, but in any case excessive iron oxide must be avoided if colourless glasses are to be made in the pots.

The reference to the behaviour of each constituent of the clay mixture when fired at 1400° is undesirable. The body obtained by firing the pot clay mixture at 1400° may have a satisfactory texture even if the constituent clays (when more than one clay is used) do not individually give a dense body when so fired. The product obtained by burning a mixture of clays may have quite different physical properties from those of the individual clays separately burned, and it is obviously the properties of the product obtained from the prepared pot clay which should be specified.

The porosity or texture of a sample of the pot clay made up and fired for a stated time at, say, 1400° may be specified with advantage and the contraction which takes place between the wet and burned conditions may have limits assigned to it. The mechanical strength of samples of the clay made up and dried by a defined method may perhaps be referred to in a complete specification. There is no doubt that this factor is of great importance in its effect on the behaviour of the pots under the necessary handling they receive before burning. For small pots or other articles which may be made from pot clay and burned before delivery for use, the mechanical strength of the fired body may be important in its influence on breakage during transit or storage.

Progress in the production of pot clays is essential to the development of the glass industry. The conditions of economical production of many types of glass which are founded in pots demand a much higher service from the pots because of the higher temperatures which are employed; but in addition to this many of the glasses which are needed for illuminating or chemical purposes have a more corrosive action on fireclay than the older types of glass.

In conclusion, the author expresses the hope that the discussion which this paper is to open will elicit information and opinions which may be utilised in revising the Provisional Specifications.

Department of Refractories,
University of Sheffield.

Discussion.

Dr. M. W. Travers thought that Mr. Rees's paper would prove a most interesting publication, and would enable them to extend the specifications and put them into effect. He was inclined to think that if, instead of using blocks 2 ft. 6 in. or 1 ft. 9 in. in dimensions, very much smaller ones were used, it would be possible to burn the blocks to a considerably higher temperature before putting them into use in the furnace, and thus obtain very much better results.

Lt.-Col. C. W. Thomas said Mr. Rees's paper had been of extraordinary interest to him, because he had apparently drawn the same conclusions as he himself came to some time ago, based on observations, extending over the last few years, of the results obtained from fireclay refractory materials in tank and pot work. Mr. Rees had also touched on some of the difficulties which manufacturers of these materials had to contend with, and if he might be excused for saying so, it was really the most refreshing paper from a manufacturer's point of view that he had listened to for a long time.

It was a known fact that one of the great troubles of the clay supplier was the variation always experienced in a fireclay seam, as one progressed along it in the working of the bed. It was not even a matter of yards, as Mr. Rees said, but very often only a matter of feet. Appreciable differences in the nature of the clay were encountered also between the top and the bottom of the seam. He was glad to hear that Mr. Rees was of the opinion, having regard to those difficulties, that the fireclay manufacturer had not done so badly after all.

Some of the points that Mr. Rees mentioned were of great importance. One of them was the question of porosity. Obviously, if one could produce a tank-block absolutely non-porous, it would be in a condition best suitable to face the action of the molten glass. The solution of the block would be delayed indefinitely. In practice, of course, one could not expect to attain to that. It was not possible to make a tank-block of the same density, for instance, as an earthenware body. The figure of 18 per cent. porosity, which Mr. Rees spoke of for flux line blocks, was, in practice, almost farther than it was possible to go, having regard to the present run of sizes.

Dr. Travers had inferred that the stress of circumstances was gradually driving the manufacturer, and possibly the user, in the direction of smaller sized blocks, with the object of getting them more thoroughly and more uniformly burned. By adopting smaller sizes the manufacturer would certainly have better control during the various processes of manufacture; he would have better control over the dimensions and would also be better able to obtain truly plain surfaces where block and block joints had to be made in the tank walls.

Another point which Mr. Rees brought up was also of considerable importance, namely, that for a successful block one must have the grog and the raw clay, if not of the same material, at any rate of such materials as had the same degree of solubility. If one had a highly refractory grog, a more insoluble grog than the binding clay used in the making up of the blocks, obviously the binding clay, as it dissolved, would leave particles of grog projecting, and this would lead to stones in the glass. The more the manufacturer could maintain equal solubility in the grog and the raw clay, the more likely he would be to make a really successful block.

Another point of importance was the question of the relative value of high-silica and high-alumina clays. He remembered directing attention to this point at the time that the specifications were provided. There was a strong feeling at the time in favour of high-alumina clays, and he believed he pointed out at the time, and had done so more than once since, that the typical pot-clay of the Stourbridge and possibly other English districts was essentially a high-silica clay. Mr. Rees pointed out, where one required great mechanical strength, as one undoubtedly did in the walls of a glasspot, a high-silica clay (and by this he meant a clay which had naturally a high silica content, and not one to which silica was added in the form of sand or anything else) was bound to give a greater mechanical strength; moreover, it tended to give a better heat transference from the outside of the pot to the inside. Therefore, he, personally, hoped that the ultimate outcome of any further work done in this direction would be to strengthen the view that, for pot purposes, at any rate, if not also for tanks, a high silica content clay would be preferred, for the reasons mentioned.

The points referred to seemed to him to be the most important and for the moment he did not propose to say more, except just this: from the point of view of a manufacturer of fireclay refractories, it was of vital importance that those who had to use, for industrial purposes, the materials which he supplied should express their views freely, stating clearly the opinions which they had formed as the result of the observations of the working of the refractory materials under ordinary furnace conditions. Mr. Rees had referred to the difficulties which the manufacturer of refractories had to face during the actual process of manufacture, and he thought he quite rightly made the point that in very many cases the user of these refractories did not always make sufficient allowance for the troubles of the refractory materials manufacturer. At the same time, it was probably equally true that the manufacturer of refractory materials was not always in the position of being able to know precisely what happened to his wares when built up into furnaces. Until comparatively lately, at all events, it was very difficult for him, in the majority of cases, to find this out. But since this and other kindred societies had developed, and much more interest had been taken in the technical control of furnaces and heat work generally, it had fortunately been easier for the manufacturers of refractory materials to get at something like a concrete idea of modern conditions which had to be met. Meetings such as this, where discussions could take place in the light of individual experience, were, in his opinion, extremely valuable to the refractory materials manufactured, apart altogether from the good purpose which they possibly served in leading to an intelligent use of refractory materials once they are supplied.

Prof. W. E. S. Turner said it fell to his lot to speak from the point of view of the glass industry, knowing as he did something of the glass manufacturer's troubles. If, therefore, he seemed to emphasise the glass manufacturer's difficulties, it was not to be assumed that the clay manufacturer, on his part, had not been giving of his best. He really believed that he had. There were, however, some things quite obviously needing remedy. During the past eighteen months—he was referring now particularly to tank-blocks—there had been cases of disheartening failure in connection with tank furnaces, especially where these furnaces had been run under what might be called modern conditions—high pressure work with the latest type of automatic machines.

There were two points which Mr. Rees in particular, during his very valuable suggestions in reviewing the subject of tank-blocks, had brought to notice, and to these two points he would like to make some slight reference. First of all, Mr. Rees thought, and quite rightly, that one should bear in mind that there had been a distinct change in the type of glass melted, and one ought to be quite sure before drawing up any new scheme for tank-block manufacture, or before, even, the existing tank-blocks were condemned, that the new type of glass was not more corrosive than the old. There was evidence both for and against in this connection. In the old types of glass batch, which so frequently contained a great proportion of salt-cake, the corrosion met with in tank furnaces was almost wholly confined—at least in its more severe aspects—to the top courses of the blocks, and one could usually predict a regular falling off in the degree of attack from the top down to the second and third courses. But the particular types of corrosion which had been encountered during the last eighteen months had not been of this particular character at all. In one special instance that he knew of, in which there was failure, it was not the first line of blocks, but the second, which was most badly corroded, and in this section the corrosion was so severe, and the blocks became so extremely thin, that a burst actually took place. This experience, then, did not furnish real evidence that the modern batch was specially corrosive. Usually the experience had been that a soda-ash batch was not nearly so corrosive as a salt-cake batch. At all events, he thought that was the general opinion, and there was experimental evidence in support of that view. This was the case in these small scale experiments referred to that afternoon, in which, when salt-cake was present, a good deal more iron was dissolved from the refractory material, and therefore presumably the refractory material itself was more attacked when the salt-cake was present. He was not so satisfied, however, that at lower temperatures, as Mr. Rees pointed out, and as was shown by Prof. Cobb, there was not some other action due to soda-ash, about which at present we knew very little. Some researches carried out by a research student in the glass department at Sheffield University about twelve months ago had shown distinctly that at about 800° there was very considerable corrosion brought about by soda-ash acting on fireclay grog. Even although that temperature was some 50° or more below the fusion point of soda-ash, a distinct action took place which corroded the fireclay material, whereas, with salt-cake at that temperature, the corrosion was much less. It might have been masked by absorption, and in some cases a gain in the weight of the fireclay material was experienced instead of a loss in weight. But certainly the soda-ash at these temperatures did appear to be distinctly more corrosive. The problem, therefore, was not one which could be considered as being by any means simple.

The second point to which he would like to refer was the question of temperature. Was it a fact that nowadays in glass tank furnaces the temperatures were higher than formerly? He was rather inclined to believe that so far as bottle tanks were concerned the temperatures were not higher : in some cases he believed they were even lower. He knew that in the Yorkshire area the temperatures used with the hard batches—batches high in salt-cake—were certainly distinctly higher than those now being employed in the case of softer batches containing soda-ash, because it was almost the universal custom to use the salt-cake batches without any reducing agent whatever and to rely merely upon the temperature and the reducing action of the flame. Therefore, the temperature could not be the main factor. It was not the temperature, because at least two severe cases of breakdown in furnaces had been known to occur in such portions as were not seriously affected by high temperature at all; where the temperature is exceedingly moderate, in fact, quite low. The first case he would refer to was that of a tank furnace which was operating an Owens bottle machine. In this case corrosion took place so rapidly that the tank burst. Now the corrosion did not take place in the melting end of the tank, but in the refining end, where chemical action had normally subsided or become spent, and where, in fact, the temperature was at least a hundred degrees lower than at the melting end. Neither of these factors, namely, chemical action or high temperature, could have operated in that particular instance. Yet corrosion took place at the refining end of the tank and it burst.

In the second case that he would call to notice both the melting end and the refining end of the tank were exceedingly badly corroded. In the case of the refining end, observations made with a pyrometer showed that the temperature was only in the neighbourhood of 1250°, and this was not a very high temperature. Moreover his experience was that blocks occupying positions where the average temperature was higher had often stood up better than those where the temperature was definitely lower. It seemed to him that what was operating was that the tank furnace had had to do some of the work which ought to have been done in the refractory manufacturer's kiln. That is, in those parts of the glass furnace where the temperatures were higher, the blocks became better burnt and denser, and in consequence stood up better than those in other parts of the furnace where the temperature was lower, and where porous blocks remained porous.

He would like the block manufacturer to think over carefully where the causes of failure lay. Instances of failure must drive them all to recognise that *some* standard was necessary! The tank-block manufacturer would not make his blocks to a specification unless the glass manufacturer himself was prepared to take them, or to ask for them. What was wanted was that the glass manufacturer himself should recognise that tank-block-makers were willing, at any rate, to consider the preparation of better tank-blocks, better in the sense that they were made to a certain specification. Until there was co-operation in this sense progress was impossible.

He knew of an instance where blocks which had been in a furnace only three months had worn from twelve inches in thickness to a single inch, and this over a wide area. In one case the blocks gave way and the tank burst. In some cases the blocks revealed big, black cores, in addition to which they were badly made, for they were full of pores. Such a state of things was creditable neither to the glass industry nor to the refractory materials industry. It ought to be realised that unless the glass manufacturer would call for a definitely better article, made to a definite standard, there was not very much hope for progress, however sympathetic and helpful the attitude of the tank-block-maker himself might be. He hoped that the tank-block-makers themselves would try to bring to the notice of the glass manufacturers that they were prepared to do their level best to meet definite requirements, and to give at least some sort of guarantee for their blocks. In these circumstances, he believed there was hope for the glass industry; but without this co-operation he was afraid the failures of the last two or three years would cause certain glass manufacturers to wonder whether mass production of glass by machinery was not going to be too costly a business.

Mr. E. A. Coad-Pryor said he must agree with Prof. Turner that the most important thing was to discover why it was that there was such a lot of trouble just now with tank-blocks. Prof. Turner had mentioned several possible causes, but it seemed to him that the crux of the whole matter was the question of the flow of glass in the tank. He thought the problem to-day was more one of mechanism than of solubility.

He would rather like to know Mr. Rees's opinion in regard to the state of the refractory materials industry in America, because it seemed to him that this was one way in which they could arrive at some definite idea as to whether British refractory materials were satisfactory or not. Many of the glass batches in the States where automatic machinery was being used were, he understood, very similar to the British, and he heard from Americans and others that the furnace life in America was very much longer than in this country. He had seen tanks in this country operated by men who had also operated similar tanks in America, with an almost exactly similar glass, but whereas here the life of the tank-blocks might be anything from three to five months, so far as he could gather, in America it was the custom to put the furnace out only at the end of the year. Occasionally, even, they went on for perhaps eighteen months. · The starting-point of all improvements seemed to be: How true were these statements? If they were true, then it was obviously their business to find out why they were true.

He was not at all convinced that the theory of skin effects on tank-blocks was correct. It seemed to him that when one had a 12-inch block the first 4 inches of that block were dissolved within the first few weeks or so: the next few inches were dissolved within the next few months; and the few inches of the block which still remained finished the work of the furnace. If that were true, then it seemed to him improbable that the slight holding back of the attack for a short period, and the consequent protection of the skin of the block were going to make very much difference.

As regards the tests to be employed, assuming that it was the mechanical action of the glass that was the major cause of the trouble, it became a matter of very considerable difficulty to devise a test in a laboratory which would meet the case. The nearest he could suggest was to blocks floating in molten glass within a tank, and allowing the wash of the glass in the tank to exercise mechanical action. Unfortunately, the blocks would float about to some extent, and there would be a certain amount of friction, but it would not be a difficult test to carry out, and he thought it would, on the whole, give good results.

With regard to the specification, one point had been omitted, and that was that no stipulation of dimensions had been included. With silica bricks a maximum variation of 0·1 or 0·2 per cent. was intimated, but it seemed to him very important that in a tank-block some indication should be made as to what was considered reasonable for dimensions. He would suggest plus or minus 1½ per cent.

In dealing with the general question of the life of the tank furnace, it seemed to him that it would be of some use to trace out the stream lines of the glass. He thought that would explain some of the peculiar phenomena of the attack over broad areas below the surface, and a good deal of valuable information would thus be obtained. He thought it would probably be a paying proposition to modify the shape of the tank and depart from the more orthodox practice now that much more glass was drawn through the tanks than formerly.

Mr. G. V. Evers said Mr. Rees referred to the filling up of the tank with a certain amount of cullet. He would like to ask him his opinion on this point. Some users said, use no cullet; others said, use some cullet, and so on. In any case, one point had always struck him, and he thought it might be worth the attention of the users of tanks. When cullet was put into a tank and heated up, it sank down as it melted into very much less bulk, and it lay at the bottom of the furnace. He was given to understand that when this happened, the tank got a charge of batch. But, surely, if it was worth while putting cullet in at all it ought to be worth while adding more cullet as the bulk diminished, because the blocks which one needed to protect with the cullet were those of the flux line.

He would also like to ask Mr. Rees if he considered that tank-blocks were better made with grog composed of either old tank-blocks or of lump clay burnt. It was a question which had been raised before. He himself raised it on a previous occasion; but it still remained unanswered. There was a sharp division of opinion on the subject. He would like to ask what Mr. Rees thought now. Had he developed that matter any further?

Thirdly, with regard to the sizes of the blocks, was it possible to use smaller blocks, as Dr. Travers suggested? Porosity was stated to be an important factor in the case, and it certainly was true that it was more difficult to obtain low porosity in very large blocks than in comparatively small ones. It might be worth while to risk having a larger number of joints for the sake of a lower porosity in each individual block.

In the making of gas retorts manufacturers were asked to provide not less than a certain porosity. The gas engineers want a certain porosity: as a matter of fact they wanted not less than 20 per cent. Now when a gas retort was being fired in a kiln one was dealing with a material only about 3 or 4 inches thick, and heat could be applied to both sides of this retort wall. One could, therefore, get heat through very much more readily. In the manufacture of gas retorts the difficulty had been to raise the porosity to what was required, and there had been considerable difficulty in getting it above 20 per cent. In the making of tank-blocks, however, their task was to get the porosity *down* to 20 per cent. In the one case we have a comparatively small thickness to deal with, easily penetrated by the heat supplied, and in the other case a very large block, to the inner portion of which it was very difficult to apply the full degree of heat necessary. He would commend this matter to the consideration of users of tank-blocks, and ask them to reflect seriously as to whether it was not worth while making trials with blocks of smaller sizes.

Mr. W. J. Rees: Prof. Turner rightly directed attention to the variations between the modern temperatures of tank furnace melting and those employed a few years ago. Possibly in many cases lower temperatures were employed nowadays because of the much softer glass that has to be melted. What he wanted to suggest, although he evidently did not give quite the right impression, was that not only was the melting temperature important but also the viscosity of the resultant glass. It was the viscosity of the resultant glass which was an important factor. As both Prof. Turner and Mr. Coad-Pryor indicated, the corrosion of tank-blocks below the level of the glass was due rather to mechanical than to chemical action. But in any case the less porous block—and therefore the mechanically stronger block—would resist both the mechanical corrosion and the chemical corrosion better than a more porous block. Some real knowledge of the metal stream lines in a tank, as Mr. Coad-Pryor suggested, would be extremely valuable. He had seen cases where the corrosion to within a foot or 18 inches down in the metal had been greater than the corrosion higher up. This was evidently due mainly to friction.

With regard to the bad blocks to which Prof. Turner had directed attention, some of these were obviously really bad blocks. It was a thousand pities that they were ever used by the glass manufacturer. If the manufacturer of glass who used these blocks had ordered them even to the imperfect specifications which at present existed, he was sure the results would have been better than those indicated. But in all cases of block corrosion it was important that we should have all the facts that both the manufacturer of the tank-blocks and the users of the blocks could give, in order that they might get a true impression of the causes. It was important that one should know not only the general factors, such as the porosity, the chemical composition of the block, its after-expansion, its degree of burning and so on, but also there should be available for us data as to the temperature of the furnace, the viscosity of the glass, and so forth, for without this information it would be impossible to ascertain the resistance of various types of blocks to the severe conditions which they had to meet.

There were other factors associated with the breakdown of fireclays at high temperatures in glass-melting practice. For instance, at the higher melting temperatures there would be a more complete interaction between the glass and the actual face of the block than at the lower temperatures. One came across this difficulty when dealing with corrosion of coke-oven walls due to variations in temperature. In coking salty coals, if the oven was worked at a very high temperature—a temperature very much higher than generally employed in the production of coke—then the salt present in the coal reacted on the fireclay and practically salt-glazed the bricks used for lining the ovens. But at the temperatures more usually employed in coking—that is to say, between 800° and 950°—the temperature was not sufficiently high for that salt glaze to be produced. Consequently the salt vapour penetrated the block and reactions took place—low temperature reactions—within the structure of the brick-lined coke-oven resulting in the rapid disintegration of the block. It seemed to him that this factor might play some part in the corrosion of glass tank-blocks. Perhaps it was not so important a factor in tank-blocks as in the linings of coke-ovens, but it was a factor which he thought needed some consideration.

The precise behaviour of many of the present-day highly-alkaline glasses upon tank-blocks seemed to bespeak the necessity for a good deal more experimental work. An increased chemical reaction could almost be anticipated between many of these incompletely saturated glasses—very often containing, say, 6 to 8 per cent. of lime and up to 20 per cent. of alkali—and the tank-blocks; particularly would this be the case when the tank-blocks were made from siliceous clays. At the same time, one would expect more corrosion also lower down the tank, due to the viscosity of the glass.

Mr. Coad-Pryor asked a question with regard to the state of the refractory materials industry in America. Like Mr. Coad-Pryor he had been told when in America that they got a very much better life in their tank-blocks there than in this country. In visiting various glass works, however, and in conversation with glass manufacturers he came to the conclusion that the average life of the tank-blocks used in American glass-making practice was certainly not any higher than in this country. In addition, some of the best-known American-made blocks had actually been brought over to this country and used in the glass tanks here, and had not given any better results under our conditions of practice than the British-made tank-blocks. His opinion was that the American manufacturers of refractory materials knew no more about the making of tank-blocks than was known in this country. Both had to learn quite a good deal yet as to the precise type of block wanted, and how it should be made.

Mr. Coad-Pryor's point as to the rapid wearing of blocks during the first week or two, and then the slower progressive wearing of the balance of the block, was, of course, a further argument for the use of smaller sized blocks, or at any rate thinner ones. If one used a thinner block there would be an increased tendency for the formation of a layer of frozen glass on the inside of the block. Possibly the use of a thinner block in some situations would be an advantage.

He was glad to hear that Mr. Coad-Pryor agreed that a useful test would be the floating of blocks in a tank, although he was not so confident that the glass manufacturer would always welcome such a test. It had certainly not always been the case. If a bad block was put in at the melting end of a tank, and the glass happened to throw stones, he was afraid the man who put the block in would hear about it.

Mr. Coad-Pryor also asked whether there should not be some specification as to the limits of sizes of tank-blocks. That matter was discussed when these provisional specifications were prepared. He might say that the specifications—at all events as regards tank-blocks, in which he was more intimately concerned—were more or less a compromise. They were discussed between the glass manufacturers and the manufacturers of the blocks, and he thought his recollection was correct that the latter would not agree to a minimum of plus or minus 1½ or 2 per cent. in the finished blocks. It was an exceedingly difficult matter to adjust. There were so many considerations in the making and burning of the blocks which affected their finished sizes that unless the blocks were made by hand and then machine finished, or machine planed, ground or cut, any very close approximation to specified dimensions was difficult from the point of view of the manufacturer, although a limit of size was most important from the point of view of the glass-maker.

With regard to Mr. Evers's point as to the use of cullet in a glass tank, he believed cullet should not be added until the tank was really properly heated. Even then, it was, he thought, desirable to do as Mr. Evers suggested, and completely fill the tank with cullet before adding any actual glass-melting batch. Generally speaking, better results were obtained by that first filling with cullet, but not invariably so. He had known cases where quite good results had been obtained with soda-ash batches where the tank had been filled after the first inch or two with glass batch. But in all cases it was desirable that the tank should be made very hot before filling on any cullet. If the tank could be heated to a high temperature, sufficient to close effectually most of the pores on the skin of the blocks, then he thought better results still might be obtained.

In reply to Mr. Evers's further point as to the use of grog, the difficulty of using grog from old tank-blocks was mainly, he thought, that of adequate sorting. If one looked at a piece of an old tank block one readily understood that it was rather a difficult matter to remove the whole of the slagged portion so as to get some really suitable material for grog. If the block could be got clean, then there was no reason so far as he could see why that type of grog should not be used successfully. In the making of pots he believed that the very best grog that could be got was obtained from an old but clean pot sherd, for this had been very completely burnt and vitrified. Where old pots or old tank-blocks could be obtained clean, he thought it desirable to employ them as a source of grog, because their conditions of use were likely to cause them to break up into more angular fragments; and, as he had already said, the angularity of fragment in a grog was a very important factor in obtaining a block with a low porosity. It was, in his opinion, impossible to obtain a block with a low porosity by using grog with rounded particles.

The subject was by no means exhausted, although the hour was late. It might be that some member was anxious to raise further points, and if anyone cared to submit questions in writing he would be glad to give them attention.

Lt.-Col. Thomas, in bringing the meeting to a close, said: A number of very important points had been brought out in the discussion. He would like to emphasise the point raised by Mr. Evers as to the possibility of using smaller sized blocks in glass tanks, because it seemed to him quite clear that the required conditions as to low porosity, thorough burning, uniformity of texture throughout, and accuracy of size were likely to be more easily obtained with comparatively small blocks than with bigger ones; and after all, any number of joints in a glass tank were not going to be any very great drawback providing that the blocks were so perfectly made that correspondingly perfect brick joints were obtained throughout.

XIV.—*Some Practical Notes on the Manufacture of Colourless Glass in a Tank Furnace.*

By F. W. Adams, M.Sc.

(*Read at the London Meeting, May* 17*th*, 1922.)

Introduction.

The use of colourless glass for food containers has become more general in this country during recent years. The natural tint of the contents shows to advantage in colourless glass; and since, also, people generally like to see what they are buying (especially with food), preference is frequently given to the article put up in colourless glass on account of its more attractive appearance. For this reason, such glass is gradually replacing pale green.

Owing to the fact that colourless glass is more costly to make than pale green, since purer and, therefore, more expensive materials are required, it has become necessary to reduce the cost of production in order to meet competition. Efforts are being made to bring this about by the use of automatic machinery. In the United States, glass factories have been equipped with entirely automatic machinery for the manufacture of a great variety of glassware, and so organised as to give a large output at a high state of efficiency. This is possible because in many cases the whole plant is organised for the production of one particular article of glassware and consequently tank furnace, machines, and lehrs can all be brought to the highest pitch of efficiency.

Until the demand for colourless glass has become more general in this country it will not be possible for existing factories, employing automatic machinery, to attain the necessary efficiency as to enable them to reduce the cost of production sufficiently to compete with certain types of glassware at present made of pale green glass.

At present a number of tank furnaces are at work in this country producing colourless glass, and it is hoped that these notes may interest persons who have control of them. The author's observations were made on a tank furnace of 110 tons capacity with a nominal output of 25 tons per day. In dealing with practical problems in glass manufacture it is truly deplorable that, with such an old industry, it is only quite recently that any really trustworthy information on the subject has been published. It is, therefore, not surprising that pale green glass manufacturers have hesitated to embark on the production of colourless glass by the use of decolorisers while there is so little information of real practical worth available, most of the so-called recipes being quite inaccurate and often misleading.

GENERAL CONDITIONS FOR SUCCESSFUL OPERATION.

The Tank.

The first essential in the production of colourless glass is a suitable tank furnace, since, as will be shown later, improper working conditions profoundly affect the quality of the ware as regards colour, appearance, and durability. In any case, whatever method of manufacture is adopted, whether hand, semi-automatic, or entirely automatic, the main operations of glass-making must be carefully carried out, namely, the melting, fining, and settling. The tank must be sufficiently long and deep enough for melting and fining to be complete before the metal passes through the doghole. The nose of the furnace should be large enough to allow the metal to settle and become uniform as regards viscosity. This is especially necessary when using certain types of feeders and machines. In fact, the nose or working end should have a slightly greater capacity than the designed daily output for the tank.

Character of the Tank Blocks.

The use of suitable blocks is a point to which careful attention should be directed as colourless glass batches, especially for automatic machines, require to be fairly soft and consequently are very corrosive. Generally the higher the soda-ash content of the batch the higher should be the alumina content of the block. The following is the percentage composition, by analysis, of a block which stood very well.

SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Na_2O.	K_2O.
58·9	37·58	1·71	0·54	0·47	0·36	0·84

The grain was fairly close.

The three photographic illustrations (Plate I, Figs. 1, 2, and 3) show the comparative corrosive effects of a high soda-ash batch on blocks containing, in the one case, a high percentage of alumina and in the other a high percentage of silica.

Fig. 1 is a view of the tank furnace looking towards the working end. The bridge was built of blocks which contained a relatively high percentage of alumina as shown by the chemical analysis given above. The faces of the bridge blocks shown are those nearest the melting end of the furnace. The top course of blocks in the nose of the tank contained a higher percentage of silica than

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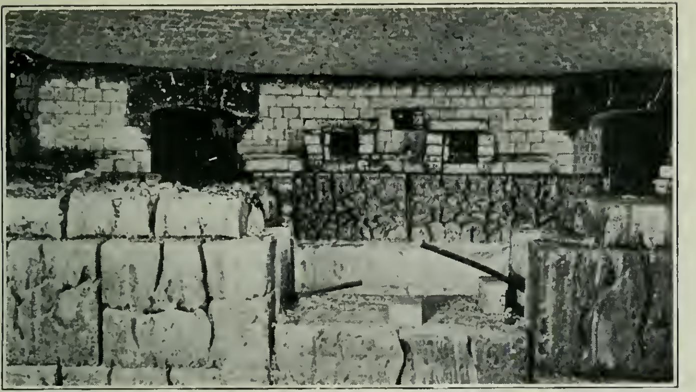

Fig. 1.

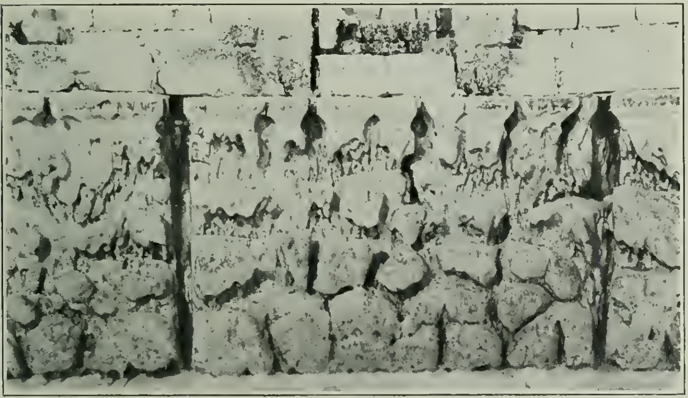

Fig. 2.

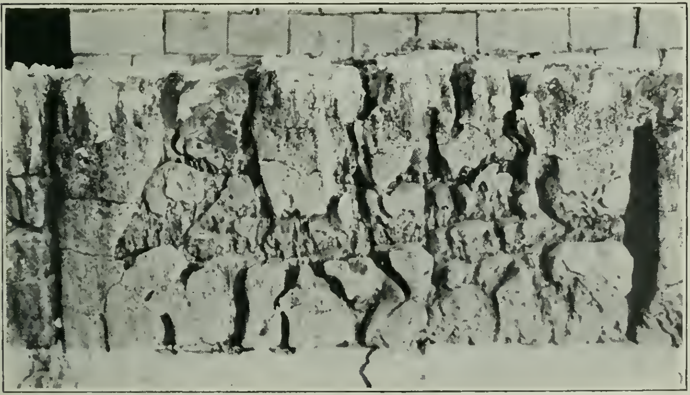

Fig. 3.

[*To face Trans., p.* 206.

the bridge blocks, and, although at a lower temperature, these blocks showed considerably more corrosion.

Fig. 2 shows a nearer view of these blocks.

Fig. 3 shows the same type of siliceous block about 8 feet from the melting end of the furnace.

The Batch.

The next and most important item is the batch, and here I would point out that glass-makers generally, not only with colourless, but also with pale green glass, would save themselves a good deal of worry and expense if they directed more attention than they do at present to the weighing out and mixing of the ingredients and also had regular chemical tests made both of the components of the batch and also of the finished metal.

In order to produce good colourless glass, a mechanical mixer is essential as the amounts of decoloriser required are so small that bad mixing will result inevitably in patchy colour. In adding the decoloriser, it has been found that quite as good results are obtained by shaking it up with about 1 lb. of dry sand or soda-ash before adding it to the main bulk of batch in the mixer as by other, more elaborate, methods. It is absolutely necessary for consistently good results in making colourless glass to have careful analyses made of every ingredient of the batch and also of the finished glass.

Function of the Decoloriser.

The next consideration is a proper understanding of the *function* of the decoloriser. This, of course, is not the elimination of the green tint produced by the iron oxide, but a " covering " effect produced by the addition of a complementary colour, which gives a neutral effect to the eye. In the case of green, the complementary colour is pinkish-red. There is obviously a limit to the depth of green, produced by iron oxide, which can be so neutralised, and it must be borne in mind that the greater the iron oxide so decolorised the less brilliant will be the resulting glass.

Choice of a Decoloriser.

There are two substances in general use for producing the tint necessary in glass to cover the green. They are manganese dioxide and selenium. The former can only be used with an oxidising batch, and is very sensitive to changes in furnace conditions, especially on long standing, as, for example, over the week-end. It has the advantage of being slightly cheaper, and also, since larger quantities are required than in the case of selenium, less care is required in its manipulation as regards weighing out and mixing.

In the case of selenium, it will be useful to indicate its physical and chemical properties when used as an ingredient of a batch mixture as it occurs finally in the melted glass. It will then be more readily understood how its action is affected by varying conditions.

The most convenient form to add the selenium, in my own view, is as the metallic black powder. In this form, it is not affected by storage and can be obtained in a very pure state. Its composition is regular and can be easily checked and the effective selenium content determined. It is the cheapest form to use. Some prefer to use sodium selenite. This is more expensive, as more is required to produce the same effect than when using the metal. In addition, it deteriorates with keeping, especially if not in a perfectly dry place.

Selenium is readily volatile at 680°, and in the presence of oxygen is rapidly converted to the volatile dioxide. Hence a strongly oxidising batch cannot be used when selenium is employed as a decoloriser. To prevent loss of selenium through volatilisation, quick melting is essential, so that the outside of the filling becomes rapidly glazed over. Hence the higher the temperature of melting the less the selenium required. The presence of arsenic appears to be necessary for the best results when using selenium, although its function is rather obscure. Further, slightly reducing conditions in the furnace tend to develop the colour.

The colouring action of selenium in glass appears to be effected in a similar way to that in which a ruby colour is produced by copper oxide; that is, the metal is disseminated through the glass in ultra-microscopical particles in colloidal suspension and therefore any physical or chemical change which gives greater freedom to the molecules of the colouring agent will necessarily intensify the colouring effect.

The Effect of Salt-cake.

In small quantities this material causes intensification of the colour. This is probably due to the reducing effect of the sulphur dioxide produced in its decomposition. The action may be compared to that of stannous oxide in the production of copper ruby.

The Most Suitable Melting Temperature.

For consistently good results when using a decoloriser, a regular and correct melting temperature must be maintained.

This temperature is determined by the type of batch used and also by the output required. Generally for colourless glass mixtures, for automatic machine working, a temperature of 1350—1400° is found to give good results.

When using selenium, low temperature melting calls for the addition of a larger quantity of selenium to be added to the batch than when a high temperature is employed, and is liable to give a dirty brown tint to the glass. Also, if the temperature then for any reason be suddenly raised a strong pink colour is developed which is difficult to counteract. Further, glass melted at a low temperature is much more liable to a reboil, as the complete cycle of chemical reactions is not complete and will recommence if the glass is reheated before passing to the machines.

It is advisable when making changes in the amounts of the decoloriser to take frequent proofs from the doghouse so that an incorrect addition can be adjusted before the whole tank of metal is spoilt.

The Effect of Varying Lehr Temperature.

If after withdrawal from the tank the metal is decolorised correctly, it will retain its colour after passing through the lehr, provided the correct annealing temperature for that particular glass composition is maintained. If, however, the lehr is too cold the ware will be green; if too hot a pink colour will be developed. This, of course, would be expected, since the selenium exerts a greater colouring effect the longer the glass is in a sufficiently plastic condition for ultra-microscopical dissemination of the element to take place. Precisely the same effect is observed in the production of gold ruby.

From the above it will be seen that, within certain limits, the colour of the glass is an index of its successful annealing.

The Effect of Storage.

Before concluding this reference to the conditions and substances which affect the decolorising property of selenium, mention must be made of the way in which the colourless glass may be spoilt by storage in places which are exposed to strong sunlight. Under these conditions, the glass is rapidly degraded from a colourless to a strong yellow colour similar to that produced by a high percentage of ferric iron. Glass so tinted can only be restored to its original state by remelting.

For given amounts of iron oxide in the batch, it is not possible to lay down definitely any rules regarding the amount of decoloriser required, as from the foregoing it will be seen that there are many factors which tend to modify the effects of the substances used for this purpose.

General Suggestions.

The following suggestions, however, will outline the methods to be adopted to give consistently good results :—

(1) Complete analyses should be made of all batch materials used, especially the decoloriser.

(2) The total iron content in the finished glass must be kept constant and therefore the components of the glass should be checked regularly by complete analyses.

(3) Careful weighing and efficient mixing of the batch ingredients is essential.

(4) The charging of the furnace with batch should be regular.

(5) The melting temperature should be kept constant by the aid of pyrometers.

(6) The lehr should be kept at the correct annealing temperature corresponding with the type of glass and should be kept constant by the aid of some form of temperature recorder.

It is advisable to have at least two pyrometer stations in the lehr, one at the front and one at the end of the heated space, so that the proper temperature gradient is maintained. Articles differing greatly in weight should not be put together in the same lehr.

When the correct amount of decoloriser to be added has been ascertained for a given amount of iron oxide in the batch, with due regard to furnace conditions and the remainder of the batch ingredients, then the conditions necessary for good results should be stabilised as far as possible.

In the scope of this paper it is not possible to deal with details regarding the use of decolorisers other than selenium. Selenium, however, offers many advantages over other decolorising media, and will undoubtedly become as generally used in this country for making colourless glass as in the United States when the proper conditions governing its successful application are more fully understood by British glass manufacturers.

Before concluding I should like to express my thanks to the Directors of the Rockware Glass Co., Ltd., for their kind permission to publish these results; to the Glass Research Association, and especially to Mr. Leads for making the slides for this paper.

Messrs. Rockware Glass Syndicate, Ltd.
Greenford, Middlesex.

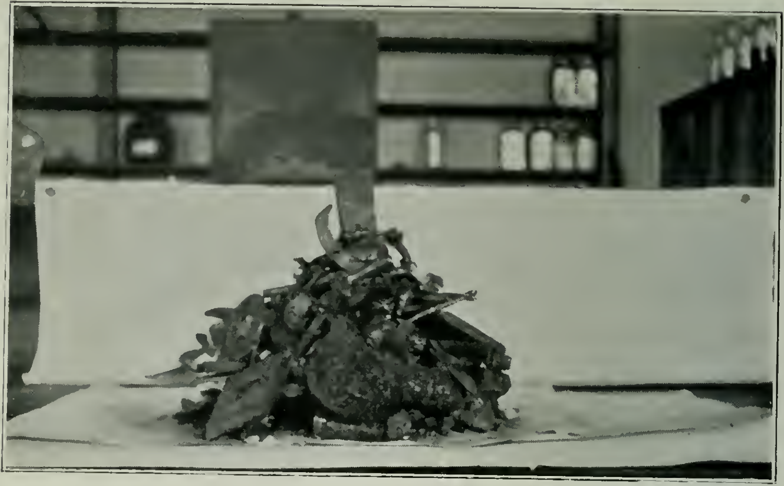

FIG. 4.

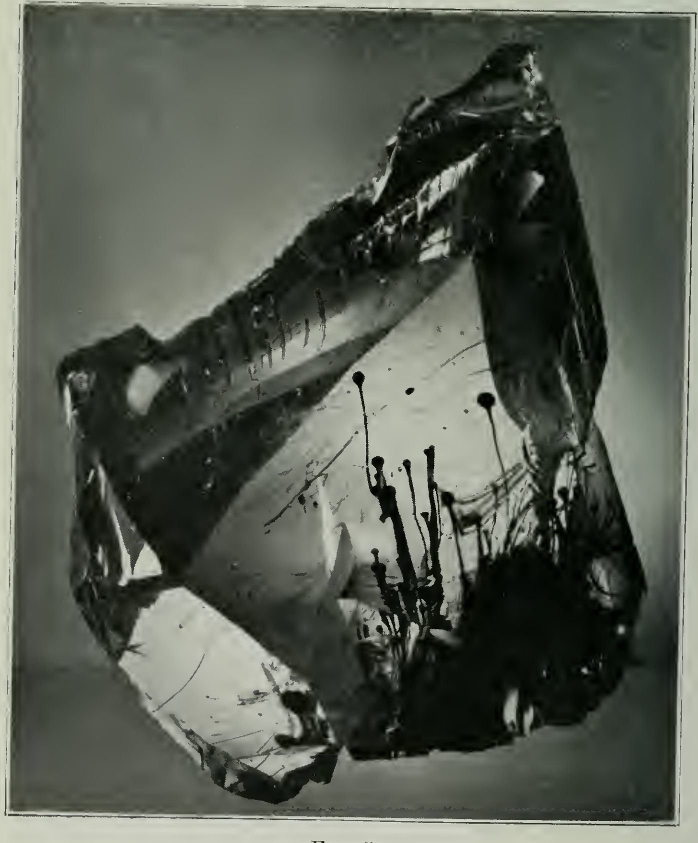

FIG. 5.

[*To face Trans*, p. 211

Appendix.

The appended photographs (Plate II) of metallic iron and its effect on the glass may be of interest to manufacturers :

Fig. 4 shows the amount of metallic iron taken from the furnace after about ten months' working. It had settled down through the molten glass and remained on the bottom of the tank and generally was distributed in a line which followed the flow of the molten glass, that is, the line from the doghouse to the dog hole.

Fig. 5 shows the peculiar effect produced by the action of the metallic iron on the molten glass, immediately in contact with it, on the bottom of the furnace.

DISCUSSION.

PROF. W. E. S. TURNER said it was not the business of the President himself to take up unduly the time allotted to the meeting as a whole; but Mr. Adams's paper was not only most useful and lucid, it was also full of discussable and debatable points. He would like to refer to three or four out of at least a dozen sections which occurred to his mind, and he anticipated that many present would also like to join in the discussion.

He was not quite sure from Mr. Adams's remarks what was his evidence for advocating the use of blocks of high alumina content in a furnace employed for the melting of the soft glasses for machine working.

Undoubtedly the type of block was most important, and although apparently the subject might appear outside the scope of a discussion on the use of decolorisers in glass, such was not the case. He himself had seen blocks so rapidly corroded that the maintenance of a colourless glass was at best a very difficult proposition. The solution of the fireclay block in itself would probably account for 0·02 or 0·03 per cent. of iron oxide, an amount that was large remembering that the total amount of iron oxide allowable in a colourless glass was exceedingly small. From this it would be realised that the rate of corrosion of the blocks was an exceedingly important matter, not only from the point of view of the furnace life, but also because of the difficulty of decolorising the glass.

He would like to ask Mr. Adams if he could give any figures from his own analytical experience of the maximum amount of iron oxide which he considered allowable in a glass described as colourless. Their own experiments at Sheffield showed that it should be somewhere in the neighbourhood of about 0·1 per cent. When the figure ran up to 0·11 or 0·12, the colour was not good, and certainly when the value 0·12 was exceeded the green tint in the glass was evident. He would like a statement from Mr. Adams as to what his own opinion was on this point.

The subject of the reproduction of colour in glass previously decolorised was an interesting matter, and particularly the yellow colour, as differing from the red colour which one got with selenium glasses in which the colours were developed rapidly. This yellow or muddy colour which developed on exposure to strong sunlight seemed to afford some evidence that the nature of the colouring matter due to selenium was rather different under different conditions. As Fenaroli suggested, when glasses which had been rapidly cooled were reheated the red colour was produced; probably due to selenium itself being deposited in a form something like gold in gold ruby glasses. But the yellow colour, which only developed slowly, was due not to selenium itself but to selenides, that is, to compounds of selenium with the sodium in the glass.

Finally, he would like to reinforce those remarks of Mr. Adams where he referred to the absolute necessity for the control of each of the batch materials. A very large number of glass manufacturers had spoken to him from time to time about the production of colourless glass in tank furnaces, and he had said, quite plainly, that there was no magic way of obtaining colourless glass in tank furnaces. It depended entirely on careful control, and one might use various decolorisers—selenium, sodium selenite, or manganese dioxide—but none of these would work correctly without some human intelligence behind it. The whole of the process needed careful periodic watching, as Mr. Adams had pointed out, in view of the varying conditions likely to be encountered.

Mr. E. A. Coad-Pryor said he would like to ask Mr. Adams one or two questions. First of all, he was not quite clear as to the position occupied in the furnace by the aluminous and the non-aluminous blocks respectively. It seemed to him from the photographs that the blocks were some distance apart, and it was quite possible that before any evidence was accepted that the alumina blocks were better than the siliceous blocks, it might be necessary to get the two sorts which were to be compared very closely together. He would be rather interested to know precisely where the blocks in question were situated in the furnace.

There were also two questions about the selenium which he would like to ask Mr. Adams. First of all, what evidence had he that the selenium was so very volatile? He understood Mr. Adams to say that if one was not careful the selenium would be burned out of the furnace, the selenium oxidising to selenium oxide. Had he determined the selenium in the glass? It seemed to him that there was some evidence to cause one to suppose the selenium did not go away at all, but merely changed into a different form, producing harmful effects, and making the glass worse than if it had not been there at all.

Again, what was the evidence that the selenium was in colloidal suspension? To his mind it appeared that this was probably not the case. It was very remarkable that one could get the colour so universal as one did with a selenium glass. One could take a piece of glass, turn it green, bring it back to pink and once again to grey. The colour was reversible.

Again, what was the value from a proof taken from the doghouse? The furnace conditions determined the colour so much, as well as the annealing, that it seemed to him a little doubtful if one could get much information in this way; but he should like to ask what information was obtainable by this means.

As regards the point raised by Prof. Turner as to the amount of iron oxide that could be decolorised, he did feel that if one attempted to decolorise 0·11 per cent. of iron oxide the results would be rather disheartening. If one wished to get a really colourless glass, he was inclined to think that it was not possible safely to go beyond 0·08 per cent. The glass sent round for inspection that afternoon had probably about 0·05 per cent. It was a very nice glass. He did think, however, that it was apt to create rather an optimistic spirit to suggest that they were likely to be successful in getting well-decolorised glass with 0·11 per cent. of iron oxide.

There were many other questions that he might have been inclined to ask, but for the eagerness of other members.

Mr. R. L. Frink would like to confirm one statement made by Mr. Adams, namely, that rapid melting was essential in order to obtain anything like a uniform colour. That, he thought, was proved by the results obtained in the average furnace. If the furnace was capable of producing, say, 20 tons of glass a day and only 15 tons chanced to melt, there was a change in the colour. That was probably at the melting end of the furnace; but Mr. Adams stated that he considered it necessary to have the fining end of the furnace of sufficient size to contain one day's production. He could not agree with that, either from the point of view of colour uniformity or of machine operation. Their experience so far, over in the United States, was that they could say quite frankly that the smaller the refining end, the more uniform the flow of the glass that passed through that refining end; and the more rapidly one could take the glass from the melting end through to the machine, the more uniform was the product in general and the higher the efficiency obtainable. Of course, one had to take into consideration the fact that one could not have a furnace so short at the melting end that the batch, before it was melted and fined, passed through the dog hole and thence into the machine; but the larger the fining end of the tank, the longer the time that the glass was kept at a high temperature, and not only the temperature but the length of the time that the glass was at that temperature, determined the colour to a certain extent. Therefore, he thought it advisable that some further information should be obtained on that aspect of the question.

Mr. J. H. Davidson said that when batch had been mixed with selenium decoloriser and left standing for about a couple of days in the neighbourhood of the charging end of the furnace, they had noticed that further decoloriser was needed to get the proper results. Mr. Frink told him frankly when this was mentioned to him that he could not believe it. However, it had certainly happened. It scarcely seemed feasible to imagine that there was any volatilisation of the selenium in the batch; the temperature could not be sufficiently high for that. The only question was whether or not, if selenium was well mixed in a fairly alkaline batch, there was any chance of it being attacked in any way by the alkali with the formation of selenite.

Dr. W. Rosenhain said, with regard to the high alumina tank block, he could confirm Mr. Adams's advocacy from quite a different point of view. Providing the aluminous block was well made, it appeared to him to be considerably more resistant to the glass than the siliceous block. But one thing must be remembered, namely, that the highly aluminous block required to be burned at a higher temperature in order to be brought into a proper condition than the siliceous, and very frequently the firing temperature was not adequate and the block failed—not because it was aluminous but because it was not sufficiently fired.

The question of producing white glass in a tank furnace was a matter of scrupulous care throughout. Careful control of the materials was, of course, essential in the first place, but there were other things which it was also essential to watch, such as various sources of deterioration of colour which had not been mentioned by Mr. Adams. First of all, there was the transfer of dust and ash from the producer. There was no question that this was one source of trouble. If one looked at the roof of a tank furnace that had gone out of action one discovered that the iron content of that roof had been enriched during the run of the furnace. Now that iron did not come from the batch, and even although the tank might be made a receptacle for scrap iron, as it sometimes was, he did not think that the iron would find its way to the roof. He thought the real source of the iron was the dust from the producer, and unless the plant was so designed as to avoid the possibility of that dust from the producer reaching the tank, it would be difficult to obtain a really satisfactory colour.

The question of the change of colour which these decolorised glasses underwent when exposed to strong sunlight was an interesting one, and he did a good deal of work upon this subject some years ago. The conviction he reached then was that the whole action depended not so much on anything happening in the decoloriser itself, whether selenium or manganese or anything else was used, but on the state of the oxidation of the iron in the glass. He thought it was quite possible that sunlight might effect the transfer of oxygen from the iron oxide, thus liberating the iron in the glass. The only element that one was likely to have that would serve as a receptacle for the oxygen so freed was arsenic. It was a perfectly possible cure for these troubles. If one avoided arsenic, one lost some of its advantages. He knew, of course, that a colourless glass had been made entirely without arsenic and it was quite possible to do so. One could scarcely blame the decoloriser used in a glass for these after-changes in the colour due to exposure to sunlight. It was well known that the ancient glass from church and cathedral windows which had been exposed to the light was of quite a different colour from that portion of the glass which had been covered by the lead. It was also well known that a strongly exposed photographic negative which was afterwards cleaned definitely bore a trace of the original image, which could afterwards be printed up.

Mr. Donald Turner said that in regard to the point which had been raised concerning the firing temperature and the physical properties of the tank blocks, particularly as regards porosity, he might say that he made certain experiments about a year ago which suggested that the difference between the corrosion of aluminous and siliceous fireclays was not so great as one was commonly disposed to believe, although, providing that the aluminous blocks were fired to a fairly high temperature, the corrosion was rather less than with the siliceous blocks. The firing temperature itself made a great difference to the rate of attack. He thought it would be an advantage if Mr. Adams could give them some details regarding the temperature of the firing of both types of blocks, and particularly some details as to the porosity.

Mr. W. B. Clarke said, with regard to the effect of sulphur or any other impurities in the gas or the oil used for firing these tank furnaces, he would like to ask whether anything had been done experimentally with other oil or gas entirely sulphur-free. It was known from various papers which had been read before the Society that sulphur had a pronounced effect on the surface of a glass as well as on the colour. During recent years, in the course of a study of the lamp bulb problem, in which he was particularly interested, an attempt had been made to get bulbs out of tank furnaces, but not much success had been achieved, chiefly on account of the colour, but also in consequence of other difficulties. The same trouble had been experienced in making bulbs in producer-gas-fired furnaces in which open pots were used. The only satisfactory way appeared to be to make the bulbs in closed pots.

With regard to the colour of the glass, he supposed that at the present time there was no standard for a colourless glass, a semi-colourless glass, or a pale green glass. At Powell's, a tintometer had been used for many years for matching the colour, but it would be well to know if any standard of colour had been set up, and if it could now be clearly defined when one passed from a colourless to a semi-colourless or a coloured glass.

There was another point in regard to the corrosion of the blocks. No mention was made as to whether the corroded blocks were exposed rather more to the flame or whether they were on the surface, where one would expect that the fluxes might exert a considerably varying effect according to whether one was using siliceous or aluminous blocks.

Mr. Guy Simpson said he would like to ask whether Mr. Adams could venture an opinion as to why a small quantity of organic matter present in the batch materials should so very much affect the colour with an oxidising atmosphere.

Mr. E. A. Coad-Pryor remarked that it had always been his custom to make a little balance sheet showing the iron in the glass, where it comes from, so much from the sand, so much from the lime, and so on, and afterwards analysing the glass to find out how he stood. There was always an additional amount which could not be ascribed to introduction through the batch materials, and this excess he described as the "muckman factor," that is, the amount arising from furnace walls, ash, dirt, etc. He would like to know what Mr. Adams's "muckman factor" was. When using pretty good refractories he would say that 0·02 was a reasonable factor to take; but he would like a word from Mr. Adams in regard to this.

Mr. Ed. Meigh said, not being a chemist, and responsible for carrying out instructions in regard to materials, he was fairly convinced that in order to get a nice colourless glass from a tank, what one had to have most of all was luck, and when one found that one's chemist, instead of analysing the materials properly and seeing that they were properly mixed, gave one something like the lump of iron that was shown on the slide, they would realise that his view of the matter was probably a correct one. There was perhaps one little way in which he could contribute to the discussion that afternoon, and it was this: He did not know whether any of the members present took in that new American journal which he saw on the table, namely, *The Glass Container*, but for the benefit of those who did not, he would like to mention that in the May number there was a rather excellent article on the manufacture of white glass in tanks, by the president of an American glass-manufacturing company, who explained some of the things which Mr. Adams, with modest reluctance, had refrained from explaining.

Mr. R. L. Frink said, in view of what had just been said, he might perhaps mention that there was some considerable controversy a little time ago over a shipment of glassware that was sent to a pickle manufacturer, and it was submitted that the excess of alkalies present had increased the solubility of the glass, causing poisoning. Arsenic had also been used in conjunction with selenium and had contributed to some form of poisoning. An incident of a somewhat similar kind had recently occurred in England. Now the glass-container manufacturers over in the States naturally realised that if anything of that kind was liable to happen, the general public was likely to drop all forms of food contained in glasses, and that, therefore, such statements should be disproved. It might be well for those who were members of the Society of Glass Technology to take this matter into their careful consideration. In the States it had been proved conclusively that if the solubility of the glass is increased through the pressure of alkalies, then the use of either the selenium or the arsenic should be carefully controlled; but a better plan would be not to let the alkalies reach such proportions as to make the glass soluble.

Prof. W. E. S. Turner said there were two other points that he might have mentioned. The first was this: One glass manufacturer complained to him that when the sand was wet, it affected the decoloriser. It became streaky and he did not get good results under such conditions. The second was as to whether or not the seediness which was at times to be seen in colourless tank-made glass was at all to be ascribed to the volatility of the selenium, in much the same way as one got a boil very frequently in the production of amber glass when sulphur was the main source, or one of the sources, of the colour. Perhaps Mr. Adams might be able to tell them something on this point.

Mr. Adams said he was afraid he had a rather formidable set of questions to deal with, and that if he was to get through them it must be very briefly.

First of all, with regard to the corrosion of the tank-blocks, perhaps he did not make it sufficiently clear that the aluminous and the siliceous blocks that he took for comparative purposes had operated in the same tank.

With regard to the maximum iron oxide to be decolorised, he was inclined to think that anyone who was desirous of decolorising 0·11 was rather an optimist. He should be disposed to put the safe figure no higher than 0·08.

As to the suggestion that wet sand affected the decoloriser, he could only say that he did not remember a single occasion on which they had used dry sand.

With regard to the seediness in the glass, he would prefer to leave this point over until a later date.

As to the position of the blocks in the furnace, the high-alumina blocks which showed the least corrosion formed the bridge. The slide that was shown was the bridge side of the block nearest the doghouse. The corrosion of the other blocks took place right in the nose of the tank, which was, of course, at a lower temperature.

With regard to the volatility of the selenium, he could only say that in making selenium ruby glass he had found that one often required to use very considerably more selenium than was actually found in the glass by analysis. The amount in the glass for decolorising was very very small compared with that which was put into the glass to obtain a ruby colour. He was speaking now of glass made in a pot furnace.

Replying to Mr. Coad-Pryor's question as to the advantages of proofs taken in the doghouse, he usually took these merely for his own personal satisfaction, in case at any time he might find that a mistake had been made, and perhaps something other than selenium put in. In this way he could prevent a whole tankful of metal being spoilt.

With regard to the question as to the condition of the selenium in the glass, he thought every one present would agree that there was a considerable difference of opinion as to how exactly the selenium was disseminated through the glass, and he thought that the latest theories tended to prove that the effect was something in the nature of a colloidal suspension.

With regard to Mr. Frink's remarks on the question of the size of the nose of the tank, he agreed that the colour of the metal was not improved with long standing. But as Mr. Frink knew, their tank was rather shallow, and consequently the increasing of the size of the nose of the tank gave them an opportunity of allowing the metal to get into a fairly uniformly viscous state so that the machine working of it was very much easier.

In reply to Mr. Davidson's question as to the standing of the batch in the unmelted or partly melted region of the tank, in his own case he had never had that experience. They had certainly had occasions when they had had mixed batch standing for a week before being put into the furnace, and they had found that long standing under those conditions did not make any difference to the amount of decoloriser necessary.

In reply to Dr. Rosenhain, he ought perhaps to have pointed out that on their plant they had a Chapman agitator on the producer, and that they also used washed screened coal of a uniform size and containing very little ash. This might be the reason they had never experienced any trouble from dust and ash. Of course, if they were to use fine coal and a shallow fire-bed, they might quite likely experience troubles of that sort.

With regard to the change of colour that was produced in glass by sunlight, he must say that he had seen pieces exposed to the sunlight for quite a considerable period, and although these contained considerably more arsenic than was usually put into bottle glass, so far as he could call to mind, they had experienced no change of colour that could be directly traceable to the effect of sunlight. There was practically no iron in this glass, however, and that might possibly be the determining point.

Replying to Mr. Donald Turner's question as to the tank-blocks, the aluminous tank-blocks were very close in texture, whilst the other tank-blocks, which were high in silica, were very much open, and he thought would contain considerably more grog, since they appeared to be of a coarser nature. With regard to the firing temperature, they got up fairly slowly first of all to about 1000°, then up to 1250° or 1300°, and afterwards continued at that temperature or from that to 1350°.

In reply to Mr. Clarke's question as to sulphur, he thought that, to a large extent, the effect of sulphur depended on the type of batch that one used. Possibly the particular glass to which he referred was a lead glass. In that case it would be rather more easily attacked than an ordinary soda-lime batch.

With regard to Mr. Simpson's point as to the organic matter in the sand, it was quite correct that the furnace atmosphere might considerably neutralise the effect of this, but the important point seemed to be this: If the organic matter was liable to vary and exert a variable effect on the metal, was it not far better to eliminate it as far as possible and know exactly how one stood? This would obviate the necessity of making alterations in the decoloriser, which would have far more effect on the glass than the addition of a small amount of nitrate of soda to get rid of the organic matter present. He knew of one case where carbon was present in the glass and its effect on the colour of the finished glass was very considerable.

Any further questions he would be pleased to deal with later in a communicated form.

XV.—*Improvements in Connection with Gas Reversing Valves for Regenerative Furnaces.*

By F. W. KNOWLES.

(*Read at the Leeds Meeting, November 16th,* 1921.)

IN gas reversing valves of the ordinary type the valve seating is liable to get warped or burned away, thus allowing a leakage of gas to the stack flues. This burning and warping is due to the current of hot waste gases turning downward over the valve seating on the way to the stack, alternating with the hot producer gas impinging on the sill on its way to the furnace. Any leakage of gas between the valve and its seating further aggravates the distortion or deformation of the sill, thus permitting an increasingly rapid escape of gas.

An examination of defective valve seatings showed that practically always the burnt and distorted portion was on the underside, thus indicating that the deformation was no doubt assisted by the fact that this portion of the valve seating was not cooled externally, but was completely surrounded by hot flues and brickwork. In order to obtain suitable external cooling for this portion of the valve seating, a space through which atmospheric air can circulate freely is provided on the underside of the metal forming the sill or valve seating. For this purpose, the bedplate of the valve is lowered about 3 inches and separated from the side of the port, thus leaving a channel open to the atmosphere at both ends and providing air cooling to that portion of the valve seating which is ordinarily built up solid. As an alternative to this method of providing cooling air, a passage may be constructed between the port sill and the brickwork setting.

The accompanying figure clearly shows the air cooling passage and illustrates a construction which has been found to be very satisfactory in practice.

This improvement has been patented.*

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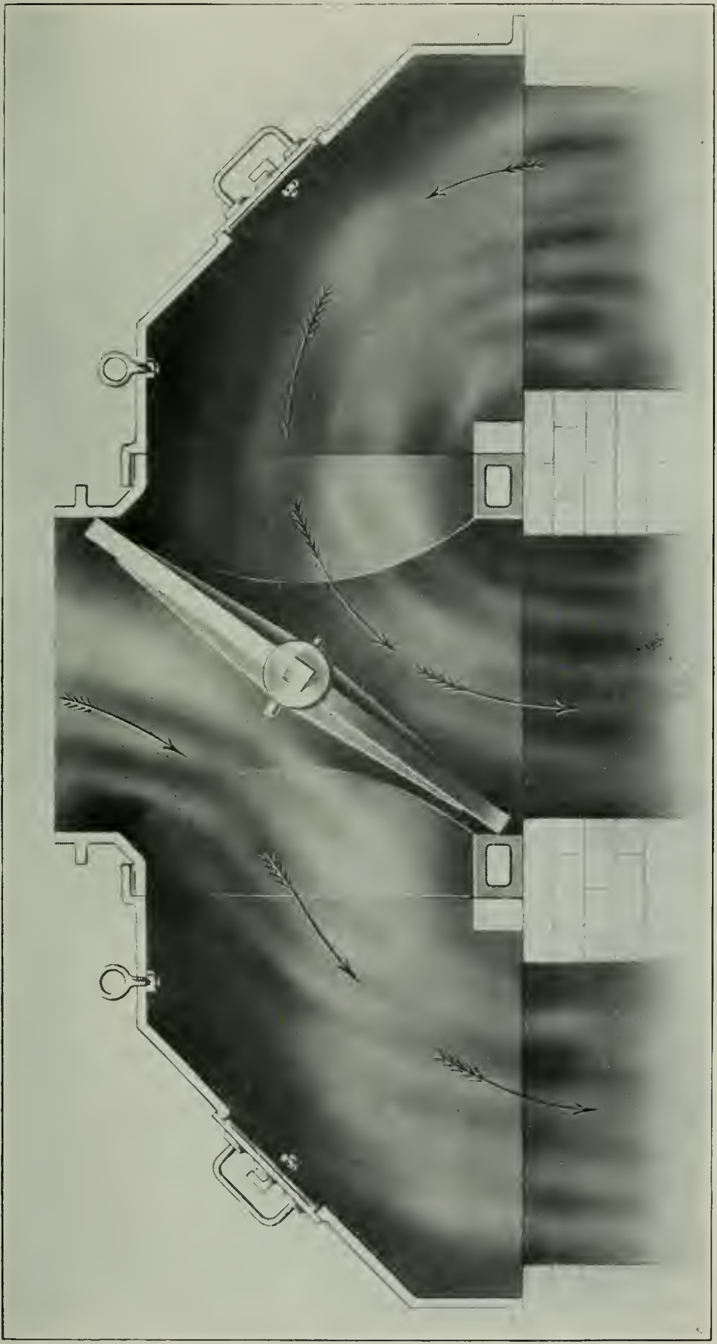
* No. 128823/1919. Application date October 24th, 1918. No. 17352/18.



The 1918 Air-Cooled Gas Reversing Valve.
(Kilner Brothers, Ltd., Thornhill Lees.

[*To face Trans, p.* 220.

XVI.—*The Composition of Lime Suitable for Various Purposes in Glass-making.*

By Miss V. Dimbleby, B.Sc., and Prof. W. E. S. Turner, D.Sc.

There has recently been published in America a Provisional Specification for limestone for use in the manufacture of glass. The specification was issued by the Bureau of Standards and is as follows:

Table I.

Composition of Non-volatile Portion.

	Class 1.		Class 2.		Class 3.	
	Max.	Min.	Max.	Min.	Max.	Min.
CaO + MgO	—	96	—	91	—	83
Fe_2O_3	0·2	—	0·4	—	0·8	—
Sulphuric and phosphoric anhydrides	1·0	—	1·0	—	1·0	—
SiO_2	4·0	—	9·0	—	17·0	—
Al_2O_3	3·0	—	5·0	—	5·0	—

The specification, as will be seen, attempts to divide possible limestones into three classes and specifies the minimum amount of calcium oxide and of magnesium oxide which should be present, as also the maximum amount of various impurities.

We ourselves have been interested in this question of the purity of limestone and limespar for a considerable time, since questions concerning it have constantly cropped up in our relationships with glass manufacturers. We have, indeed, had the thought of suggesting a specification, but, ultimately, have not ventured to do so because, whilst there would be some undoubted advantages, there are also disadvantages. The possibility of using a particular brand of lime or limestone depends on several factors, including the price, and no specification, without being complicated, can meet all the circumstances. Far better, instead of working to a stereotyped specification, which may cause him unnecessary expense, that the manufacturer should engage a glassworks chemist or technologist, to control his raw materials.

Five special impurities are mentioned in the above specification as likely to occur from time to time in specimens of lime or limestone. In the case of at least two of them, namely, silica and alumina, they are themselves glass-making materials and therefore not necessarily harmful; and provided the sulphuric and phosphoric anhydrides are also small in amount they likewise present no difficulty to the glass-maker.

Whilst, therefore, silica and alumina, in particular, may in some specimens be present to a considerable amount, the importance to the glass-maker is perhaps as much one of price of the material as of any serious consequence to the melting of the glass. Lime or limestone is, as a general rule, dearer than glass-making sand; hence if it contains several per cent. of silica the purchaser is not acquiring value for money. On the other hand, if only silica and alumina, and perhaps even a small amount of sulphuric and phosphoric anhydrides, are present, it may be cheaper for the manufacturer to purchase a less pure material in preference to a limestone which is practically pure calcium carbonate or calcium and magnesium carbonate. If he has technical knowledge or employs a chemist, which is the crux of the matter, any slight change in the batch necessary because of the lime or limestone containing silica or alumina can be adjusted. It is to the advance of technical knowledge that the manufacturer must look in order to safeguard both his glass and his economic interests.

It is rather a different matter, however, with the remaining impurity, namely, the iron oxide; for in many cases the manufacturer desires to obtain a colourless glass and in this connection he must be careful of the iron oxide content of his sample of lime or limestone. We propose to deal briefly with this aspect of the subject and to indicate the principles on which the limestone or limespar should be selected.

In general, the different types of lime-containing glasses can be distinguished as colourless, pale green, and dark green. The essential difference between them lies in the amount of iron oxide which is present.

Colourless Lime-containing Glasses.

A colourless lime-containing glass may contain a variety of other constituents and may be made either in pots or in a tank furnace.

Concerning the materials present with lime, the common ones are sand, soda ash and salt-cake. In some cases there may be potash, sodium or potassium nitrate, or again in some cases lead oxide.

Except in the case of the finest optical glass, colourless glass in commerce is always obtained by the aid of a decoloriser, usually manganese dioxide in a pot furnace and selenium in a tank furnace.

Now, in order that decolorising may be possible, the total amount of iron oxide present in the glass must not exceed a certain small value. In the case of colourless glass made in a tank furnace, and decolorised by selenium, the total iron oxide derived from all sources must not exceed 0·09 per cent. This we have actually demonstrated by experiment.

In the case of colourless glass made in pots, we have not yet arrived at an experimentally determined figure, but our experience would lead us to set as a limit a somewhat similar figure for the iron oxide content. We do not think there will be found to be much difference in the two cases, and for the purpose of the calculations below we shall assume the same limit to apply whether for a pot or for a tank furnace.

For colourless glass containing lime, the choice of the lime must therefore be decided with reference, not only to its own iron oxide content, but also to the iron oxide content of the other constituents of the batch. It cannot be fixed absolutely for itself. The sand, for example, always contains a definite amount of iron oxide, usually at least 0·02 per cent., whilst the actual amount may be considerably greater than this. The soda ash is usually the freest from iron oxide of all the common glass-making materials. From a large number of specimens examined by us, we have found an average value of 0·015 per cent. of Fe_2O_3. If salt-cake is present, the amount of iron oxide is several times greater than in soda ash. Again, from our experience, we are taking the average value as 0·15 per cent.

Even if there are no other raw materials, there are always two additional sources of iron oxide which must not be left out of account. The first source is the cullet. This represents glass which has already once passed through the furnace and has picked up a considerable, perhaps, indeed, the maximum, amount of iron oxide allowable. When added to the batch it naturally is an important source of iron oxide.

Finally, iron oxide is always derived from the furnace itself. Thus, it comes from the fireclay of the pot or from the tank-blocks, and also, in the case of a tank furnace, to some extent from the crown and from fine dust which enters with the fuel gas. The total amount of iron oxide which is added in this way is variable. In some cases, where the pot or the blocks are readily corroded, there may be added to the glass an amount as high as 0·02 to 0·03 per cent. This amount, however, is exceptional. Pieces of iron dropped into the tank, either wilfully or accidentally, naturally tend to increase the figure greatly. We cannot allow for this in the calculations. We can, however, assume with justification from our experience that an amount of iron oxide is derived from the furnace during the melting equivalent to at least 0·02 or 0·03 per cent. In our calculations, the figure 0·03 has, for safety, been assumed.

Bearing all these factors in mind, we have calculated below the degree of purity which the limespar or limestone must have in different circumstances in terms of the maximum amount of iron oxide allowable.

As the basis of calculation, we have selected three fairly typical batches, the first two corresponding with those very much in use in producing colourless glass in tank furnaces, the first also with but little modification being frequently used for colourless glass made in pots. The third glass is one corresponding more or less with a window, plate, or spectacle glass. The proportion of cullet is probably smaller than is usually employed.

In each case we have calculated the maximum amount of iron oxide which is allowable in the limespar when different qualities of sand are used. The results are as follow :

TABLE II.

Materials.	Per cent. of iron oxide in materials.	Batch.	Weight of glass.	Iron oxide in glass.
Sand	0·03	1000	1000·0	0·300
Soda ash	0·015	380	222·3	0·057
Limespar	?	200	112·0	?
Cullet	0·09	400	400·0	0·360
Furnace or pot	0·03	—	—	0·490
		Total	1734·3	1·207

Total iron oxide permissible in glass = 17·34 × 0·09 = 1·5606
∴ „ „ „ „ „ limespar = 1·5606 − 1·207
= 0·3536
= 0·177 per cent.

Hence—

If sand contains 0·03 %, maximum permissible in limstone = 0·18 %
„ „ 0·04 „ „ „ „ = 0·13 „
„ „ 0·05 „ „ „ „ = 0·08 „
„ „ 0·06 „ „ „ „ = 0·03 „

TABLE III.

Batch containing Small Amount of Salt-cake.

Materials.	Per cent. of iron oxide in materials.	Batch.	Weight of glass.	Iron oxide in glass.	When sand contains iron oxide.	Iron oxide permissible in limespar.
Sand	0·03	1000	1000·0	0·300	0·03 %	0·166 %
Soda ash	0·015	370	216·4	0·055	—	—
Salt-cake	0·15	15	6·6	0·023	0·04 %	0·116 %
Limespar	?	200	112·0	?	0·05 %	0·066 %
Cullet	0·09	400	400·0	0·360	0·06 %	0·016 %
Furnace or pot	0·03	—	—	0·491	—	—
		Total	1735·0	1·229		

TABLE IV.

Materials.	Per cent. of iron oxide in materials.	Batch.	Weight of glass.	Iron oxide in glass.	When sand contains iron oxide.	Iron oxide permissible in limespar.
Sand	0·03	1000	1000·0	0·300	0·03 %	0·096 %
Soda ash	0·015	290	169·6	0·044	0·04 %	0·067 %
Salt-cake	0·15	15	6·6	0·023	0·05 %	0·039 %
Limespar	?	350	196·0	?	0·06 %	0·010 %
Cullet	0·09	400	400·0	0·360	—	—
Furnace or pot	0·03	—	—	0·533	—	—
		Total	1772·2	1·260		

The results illustrate how much better it is to be able to decide whether or not to expect a certain limestone or limespar to suit all the circumstances of the case rather than to work according to a definite specification. The authors consider that from the above tables it will not be difficult for manufacturers to work out the conditions necessary when different proportions of the batch materials or of the cullet are used from those given. It will be clear that as the amount of cullet is increased the possibility of decolorising gets less and less.

Sources of Limestone or Limespar for Colourless Glass.

It will be seen from the calculations that under very favourable conditions it might be possible to use a limespar containing as much as 0·18 per cent. of iron oxide. Such favourable conditions, however, do not arise in practice so far as our experience goes, and in any case it would be much safer to allow a margin, remembering that we have been calculating on the limiting value of the iron oxide content to produce a colourless glass, namely, 0·09 per cent. The wisest course is not to work to this limit, but to attempt to bring down the iron oxide content still lower, as every reduction of 0·01 in the iron oxide content of the glass very greatly improves its appearance. In Table V. are set out some limestones or limespars suitable for colourless glass, specimens of which have been made available in this country for glass-making. Some of these specimens have been obtained direct from the supplier and some from the glass manufacturer. The analyses are our own.

Pale Green Glass (Pale Metal).

The term "pale metal" covers glasses in between the faintly tinted and the fairly deeply green tinted. Common window glass and bottle glass are the commonest varieties of such lime-containing glasses. The lowest limit, namely, that at which the green tint just begins to appear, is easy to fix, being approximately 0·1 per

TABLE V.—*Limestones and Limespars for Use in Colourless Glass.*

Source.	Total Fe_2O_3.	CaO.	MgO.	Al_2O_3.	Loss on ign.	Non-vol. Insol.	Total.	SiO_2.	Insol. Fe_2O_3.	Sol. Fe_2O_3.
Dowlow (Buxton)	0·01	55·28	0·30	trace	43·76	0·32	99·67	0·20	0·01	—
Precip. Chalk (1) *	0·06	55·76	trace	0·05	43·68	0·84	100·39	0·59	0·03	0·03
,, ,, (2)	0·06	55·41	0·30	0·14	43·53	—	—	—	—	—
Denbigh (lump)	0·06	56·06	0·24	0·09	43·47	0·05	99·96	0·02	0·01	0·05
,, (ground)	0·07	55·73	0·30					1	0·01	0·06
Wirksworth	0·075	54·93	0·24						0·02	0·05
Soapworks waste (dry) ...	0·10	54·30	0·54					7 (alkali present)		—

* Fr

Page.	
58	(Facing) Proc., *for* " DELLAYE " *read* " DELLOYE."
59	Proc., line 14 from bottom, *for* " Cantereine," *read* " Chant
60	Proc., line 18, *for* " M. Penir, M. Doisemaine," *read* " M. DORSEMAINE."
37	Trans., line 2 from bottom, *for* " Field " *read* " Feild."
37	Trans., line 2 from bottom, *for* " 1917 " *read* " 1917—18."
202	Trans., line 14 from bottom, *for* " θ_0 " *read* " θ."
47	Abs., line 5 from bottom, *for* " H. L. Adams," *read* " L. H
118	Abs., line 10, *for* " specific pressure " *read* " specific heat witl
233	Abs., line 15, *for* " slacks " *read* " stacks."

TABLE VII.—*Limestones an*

Barnetby (1)	0·14	54·77	trace					9	0·02	0·12
Barnetby (2)	0·14	54·67	0·25					3	0·03	0·11
Buxton (1)	0·16	54·80	0·11					1	0·03	0·13
Welsh	0·17	54·66	0·53					1	—	—
Warmsworth (1)	0·185	30·84	21·03						—	—
Warmsworth (2)	0·21	32·10	21·79						0·03	0·18
Skipton	0·21	55·44	1·05						—	—
Buxton (2)	0·29	54·31	0·38						0·09	0·20
Buxton (3)	0·29	53·38	0·10						—	—
Chemical works waste ...	0·32	54·00	0·15						0·01	0·31

TABLE VIII.—*Limestones an*

Horton (burnt)	0·50	88·26	trace						0·01	0·49
		~~$CaCO_3$~~	~~$MgCO_3$~~							
Conisboro	0·51	~~53·95~~ 30.21	~~43·78~~						—	—
Buxton (2)	0·51	52·74	0·78						—	—
Threshy	0·54	50·54	1·32						0·16	0·38
Eglinton	0·54	52·21	0·59						0·10	0·44
Buxton (3)	0·57	51·42	trace						0·32	0·25
Buxton (1)	0·68	52·18	0·74						—	—
Threshy (bottom blue) ...	0·70	52·24	1·58						0·28	0·42
Skipton	1·36	47·44	0·30						0·43	0·93
Warmsworth	1·51	30·48	20·00						0·14	1·37
Charleston	4·20	36·92	5·57						—	—

cent. The upper limit, however, at which the pale green shades off into the dark green cannot so readily be fixed. In the case of bottle glass, the following table contains the results of actual analyses and all the bottles could quite well be described by the term "pale green," despite the fact that as much as 0·41 per cent. of iron oxide is present in one case :

Table VI.

Percentage Composition of Pale Green Bottle Glasses.

Oxide.	A.	B.	C.	D.	E.	F.	G.
Silica	74·53	74·44	84·36	93·06 }	73·44	73·02	73·64
Oxide (Sb_2O				Sb_2O_3 }			
…le of arsenic	—	trace	trace	trace	trace	trace	trace
Alumin…nina	1·36	2·71	8·81	1·30	0·50	0·59	1·07
Iron oxide	0·41	0·23	0·33	0·30	0·13	0·18	0·25
Oxide (Mn…)	—	trace	trace	—	—	—	trace
Lime	9·95	7·12	6·70	8·70	8·64	9·56	4·94
Magn…nesia	1·19	0·10	0·34	0·17	trace	trace	0·26
Soda	12·46	15·21	12·00	15·26	16·32	15·55	19·40
Potash	0·04	0·48 }	5·18 }	0·98	—	—	0·42
Cobalt Boric		CoO }	B_2O_3 }				
Sulph…₃	—	trace	2·41	—	0·73	0·88	—

The problem of working out limits for the limestone or limespar …d in such glasses becomes in some ways more complex, since …le green glass is practically never made from so high a quality … sand as the colourless glass. By making calculations on the …sis as above set out, however, it is quite easy to determine whether or not a certain sample of limestone is good enough for use in making pale metal in combination with a certain variety of sand and other raw materials, including cullet.

Thus, we will suppose that it is desired to produce a glass which is actually pale green and therefore contains, say, 0·2 per cent. of iron oxide as a maximum. If we use the first batch formula given above as the basis of our calculation and suppose that the cullet is that actually produced on the works, and therefore already contains 0·2 per cent., and if, further, the sand used contains 0·1 per cent., then the limestone can contain up to 0·56 per cent. If, on the other hand, the sand contains 0·2 per cent. of iron oxide, then the limestone must contain only 0·06 per cent. at most.

Samples of limestone which we have analysed and found suitable in general for producing pale green glass are shown in Table VII.

Dark Green Glass (*Dark Metal*).

As it is not easy to fix definitely the upper limit of iron oxide content for pale green glass, so it is likewise difficult to set a lower limit for the dark green glass. For convenience, we may put the lower limit as 0·6 per cent. The high limit is unknown, and we have examined glasses containing three or more per cent. of iron oxide.

Fortunately, with this type of glass, selection of the limestone does not occasion serious trouble. The more iron oxide contained by the limestone the better very frequently, since its presence in the raw materials makes it unnecessary to add iron oxide as a batch constituent. The only constituents which as a rule need care in adjusting are the silica and alumina contents. The amount of the sand added may have to be diminished somewhat if there is a considerable percentage of silica in the limestone itself. For dark green glass the alumina present in samples of limestone does not in the ordinary way call for any adjustment.

We have examined the varieties suitable for dark glass given in Table VIII.

In conformity with what we have already said about the influence of the iron oxide in the sand, it will be recognised that a number of the limestones mentioned in this table could be used in making pale green glass if a suitable sand of low iron oxide content were employed in combination.

Department of Glass Technology,
The University, Sheffield.

XVII.—*The Density of the Soda–Lime–Magnesia Glasses and some Observations on the Calculation of Density.*

By S. English, M.Sc., and W. E. S. Turner, D.Sc.

We have shown in previous papers * that whereas, in the trisilicate glasses of general formula $6SiO_2,xRO,yNa_2O$, (where $x + y = 2$) substitution of the soda by lime brings about an increase in density, similar replacement by magnesia produces a specifically lighter glass. The glasses containing the mixed bases lime and magnesia would be expected to have densities intermediate between those containing only the single base.

The actual densities determined at 25° on thoroughly annealed, powdered, glass by the method previously described, were found to be as follows:

* This Journal, Trans., 1920, **4**, 126, 153.

	Percentage composition.						
Glass No.	SiO_2.	CaO.	MgO.	Na_2O.	Al_2O_3.	Fe_2O_3.	Density.
9	74·96	9·36	0·28	14·88	0·42	0·16	2·4757
490	74·76	7·52	1·64	14·84	0·93	0·08	2·4637
491	74·74	6·43	2·58	14·98	1·02	0·06	2·4569
492	75·58	5·48	3·66	14·48	0·87	0·07	2·4496
493	76·32	3·82	4·10	14·58	0·87	0·07	2·4364
494	76·00	3·14	4·85	14·98	0·90	0·08	2·4265
331	76·68	0·14	6·87	15·78	0·42	0·36	2·4055

Like the thermal expansions, substitution of lime by magnesia or *vice versa* brings about a continuous change in the value of the property, and there is no sign of a minimum such as there is in the annealing temperature.

On the basis of the above results, we propose to refer again to the subject of the calculation of the densities of glasses. For there has recently appeared a paper by W. L. Baillie,* in which the subject is reviewed mainly on the basis of existing data. This author proposes to adopt the formula $\frac{A}{D} = \frac{p_1}{d_1} + \frac{p_2}{d_2} + \frac{p_3}{d_3} + \ldots$, where A is the sum of the oxides determined by chemical analysis, instead of Schott's well-known $\frac{100}{D} = \frac{p_1}{d_1} + \frac{p_2}{d_2} + \frac{p_3}{d_3} + \ldots$, as the basis of calculation. The various factors were evaluated empirically by Baillie, and he proposed the following values, amongst others: SiO_2, 2·24; Al_2O_3, 2·75; CaO, 4·30; MgO, 3·25 when alkaline oxides are present and 4·30 if these oxides are absent; Na_2O, 3·20. The use of these factors certainly leads to much closer agreement between the calculated and the observed results than it is possible to obtain by Schott's method and factors; indeed, the agreement is very good.

Our own method of calculation, which has already been given,† has a rather more definite basis than Baillie's or Schott's, in that the assumption is made that the density of the silica is unchanged when present in a silicate glass. On this assumption, it is possible to calculate the density factor for Na_2O from the densities of sodium silicate glass, and, in turn, by substitution, the factors for other oxides.

It became necessary before making our calculations below to deduce the density factor for alumina. This was done from the results, already published,‡ for the soda–alumina glasses, with the results:

Glass No.	441	442	443	444*b*	445*d*	446*c*
Al_2O_3 factor	3·36	2·89	2·63	2·77	2·73	2·72

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* *J. Soc. Chem. Ind.*, 1921, **40**, 141 T.

† This Journal, TRANS., 1920, **4**, 153.

‡ *Ibid.*, 1921, **5**, 277.

The first value was neglected in deriving the factor, as glass 441 contained a small percentage of alumina, so that any error would be proportionately increased, whilst it was also the least stable of the series. The mean of the other five results is 2·75.

It was necessary, in the calculation, either to assume a value for Fe_2O_3, since no factor is known, or to neglect it. The iron oxide was present only as an impurity to a very small amount, and in assuming, as we have done, a value of $Fe_2O_3 = 4{\cdot}0$ no appreciable error is likely to be introduced into the calculated values of the density. With the factors previously obtained, we have :

Density Factors.

Oxide.	Schott.	Baillie.	English and Turner.
SiO_2	2·3	2·24	2·20
Na_2O	2·6	3·20	3·47
CaO	3·3	4·30	5·00
MgO	3·8	3·25	3·38
Al_2O_3	4·1	2·75	2·75

It will be noted that only in the case of alumina do our factors agree with those of Baillie.

Using these various values, the densities calculated are :

(1) *The Soda–Alumina Trisilicate Glasses.*

	Density.			
		Calculated.		
Glass No.	Observed.	English and Turner.	Baillie.	Schott.
441	2·4294	2·418	2·419	2·397
442	2·4247	2·420	2·423	2·409
443	2·4181	2·424	2·425	2·439
444*b*	2·4099	2·408	2·419	2·450
445*d*	2·4033	2·405	2·413	2·469
446*c*	2·4010	2·404	2·412	2·490

(2) *The Soda–Lime–Alumina Trisilicate Glasses.*

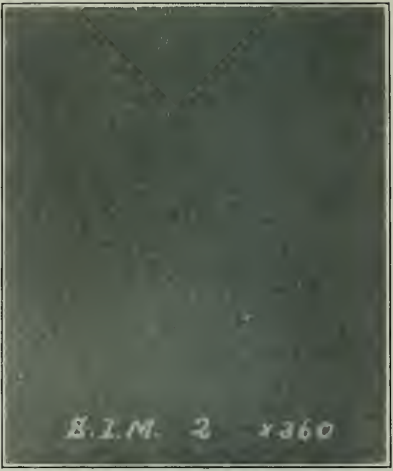
	Density.			
		Calculated.		
Glass No.	Observed.	English and Turner.	Baillie.	Schott.
458	2·4421	2·439	2·443	2·467
459	2·4498	2·443	2·444	2·446
460	2·4655	2·465	2·461	2·432
10	2·4840	2·478	2·469	2·420

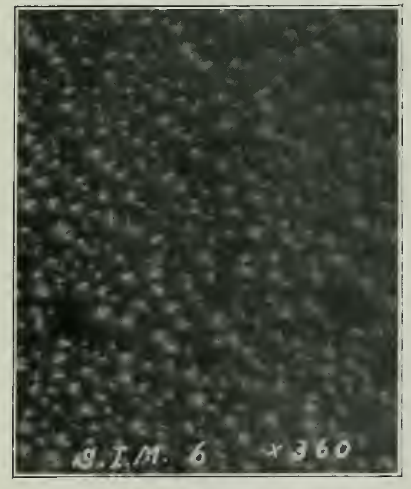
(3) *The Soda–Lime–Magnesia Trisilicate Glasses.*

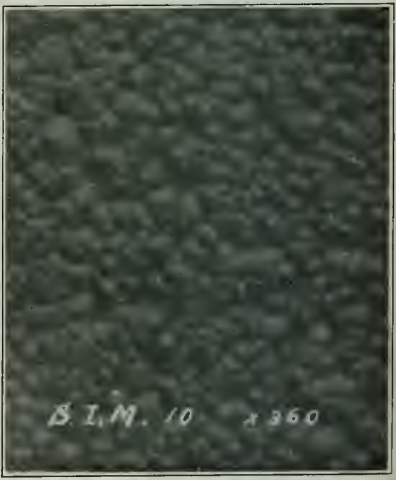
	Density.			
		Calculated.		
Glass No.	Observed.	English and Turner.	Baillie.	Schott.
9	2·4757	2·470	2·465	2·414
490	2·4637	2·464	2·476	2·441
491	2·4569	2·456	2·473	2·444
492*a*	2·4496	2·437	2·460	2·434
493	2·4364	2·426	2·444	2·436
494	2·4265	2·423	2·445	2·436
331	2·4055	2·414	2·415	2·410

280'

PLATE I.







[*To face Trans.*, *p.* 231.

Clearly the results based on Schott's factors in most cases diverge considerably from the observed values, and Schott's factors should be discarded. Between Baillie's factors and our own there is less to choose, although with the above glasses our factors are distinctly better with the soda–lime–magnesia glasses and the soda–alumina glasses, whilst they are slightly better in the case of the soda–lime–alumina glasses.

Closer agreement could scarcely be expected except by a coincidence. In the first place, our knowledge of the constitution of glass is as yet but small. We cannot say that in comparing the densities at a fixed temperature of 25° the glasses are being compared in corresponding states. Further, as the factors are only worked out to the second place of decimals, it is clear that even a slight error involved in the factor will be considerably magnified when the latter is multiplied in the calculation of the density. Schott, indeed, quotes the values of his factors only to the first place of decimals. These facts should be borne in mind by those who have occasion to determine the density of a glass by calculation.

Department of Glass Technology,
The University, Sheffield.

XVIII.—*On the Devitrification caused upon the Surface of Sheet Glass by Heat.*

By Y. Amenomiya.

(*Read at the Sheffield Meeting, June 21st*, 1922.)

It is a well-known fact that the surface of a glass plate of the type commonly used in windows becomes devitrified by the effect of heat. The author attempted to ascertain the lowest temperature at which surface devitrification would occur on glass plates, and to identify the various crystalline forms which develop on the surface as the temperature is raised. There was thus obtained a certain connection between the time and the temperature at which surface devitrification developed.

In the experiments, a small electric furnace was used and a pyrometer previously calibrated with minute care with pure metals. The first step consisted in determining the lowest temperature at which very small crystalline particles, visible with the aid of a microscope, obviously spread themselves over the glass surface.

This devitrification, it was found, did not appear below the temperature of 700° within the time limit of one hour.

The photomicrographs (magnification 360 diameters) on Plate I show the development of the surface devitrification. For example, the records with the samples S.I.M. 2 and S.I.T. 1 were as follows :

Time (minutes).	Temp.	Time (minutes).	Temp.
0	540°	12	700° Crystalline particles appeared.
3	610°	15	700°
5	650°	20	700°
7	680°	70	700°
11	696°		

The next step was to ascertain how a crystalline particle would develop in glass at the temperature of 700°, and for this reason the pieces were maintained at a constant temperature of 700° so as to develop the crystalline masses in a certain time interval, the result being that the crystalline form obtained at 700° was only spherulitic as shown in Plate II.

The duration of heating between each successive photograph was about thirty minutes. The photomicrographs were taken after a rapid cooling subsequent to each thirty minutes' heating at a constant temperature of 700°.

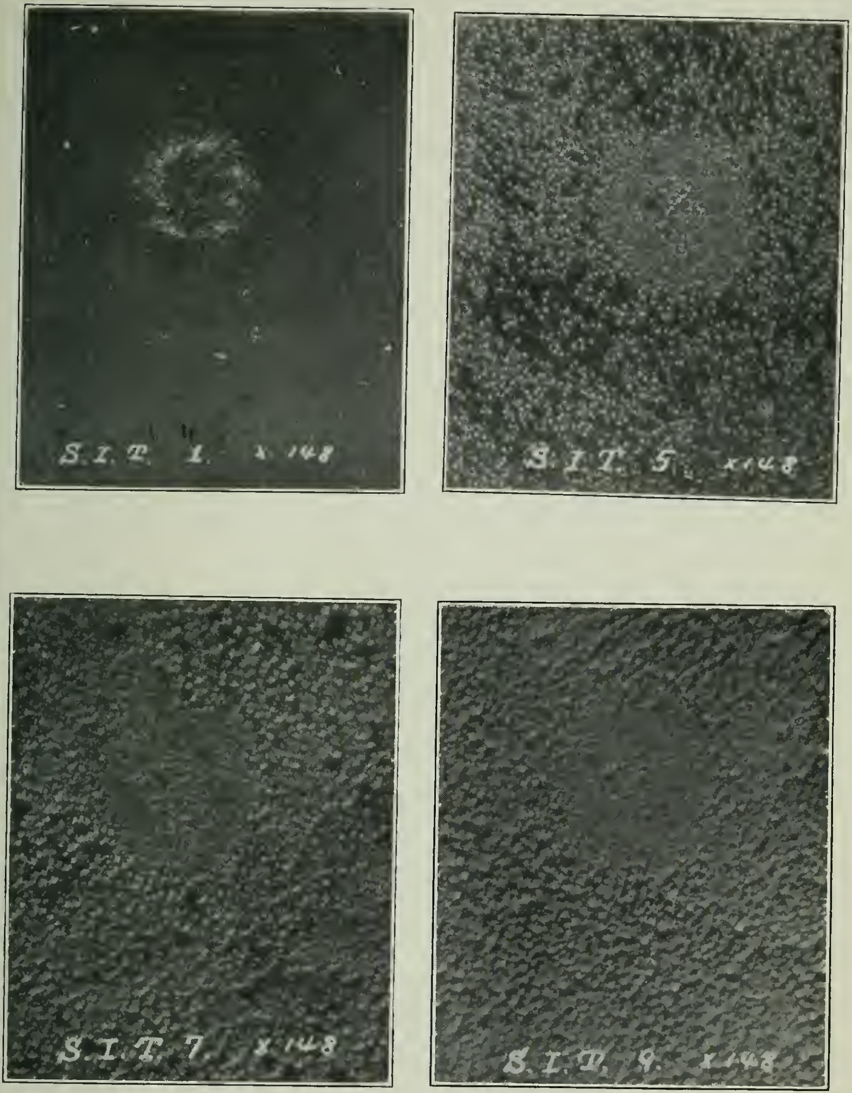
After about eight hours the pieces were exposed to a temperature of 750°, at which temperature the spherulitic devitrified mass was seen to assume the radiating needle crystal type. At 1000°, the crystals became laminated, bubbles being also seen to appear between the crystals. The photomicrographs in Plate III illustrate the phenomena observed.

Further investigation was made to ascertain at what definite point the crystals or devitrified mass would disappear and the temperature also to which the glass could be cooled without deposition of crystals. These tests gave results as follows:

Test pieces.	Temperature at which crystals disappear.
S.I.A.	1130°
S.I.T.	1115°
S.I.M.	1125°
N.A.	1085°
C.A.	1015°
F.E.	985°
P.A.	1105°

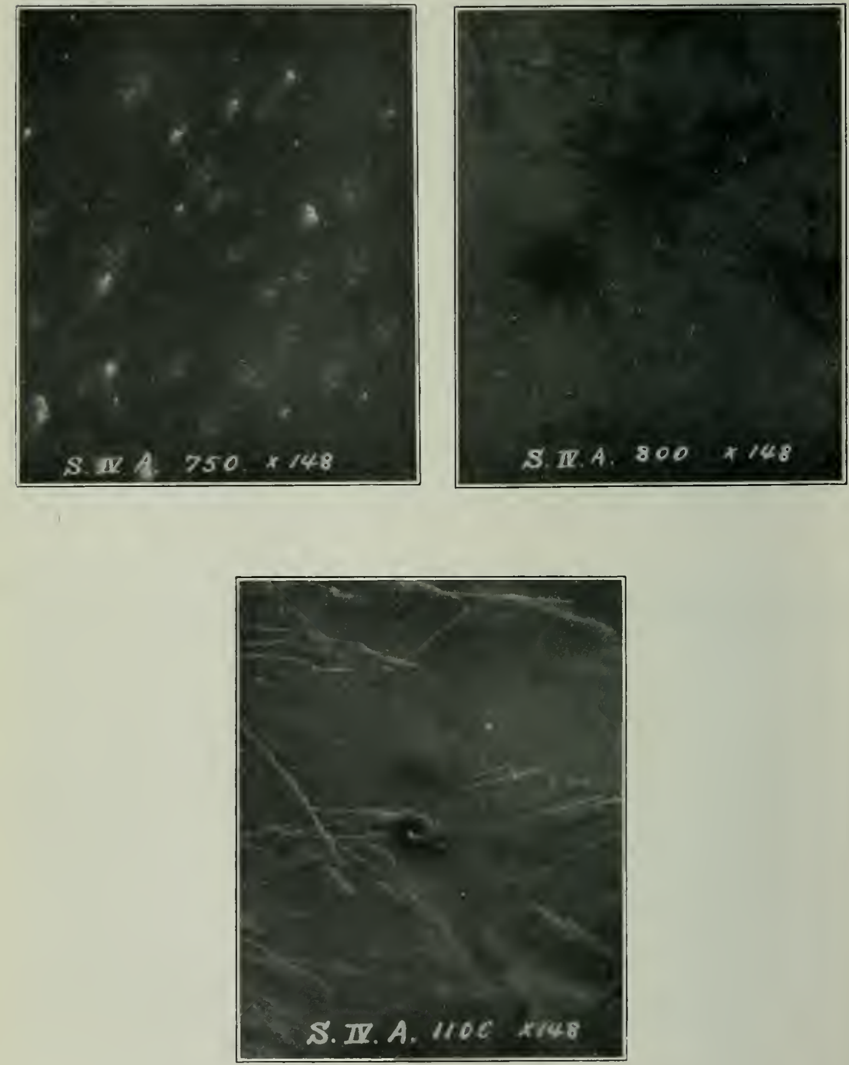
Some measurements were also made, at temperatures above 700°, on the rate of crystallisation. The following results were obtained :

PLATE II.



Appearance of glass plates after heating at 700° for one, five, seven and nine periods of 30 minutes each. Magnification 148 diameters.

PLATE III.



Change of devitrification with rise of temperature from 700° to 750°, 800° and 1100°. Magnification 148 diameters.

[*To face Trans., p.* 233.

Type of Crystallisation.

Temperature.	Time of heating (minutes).	S.I.A.	S.I.T.
950°	1	Needle crystals	Spherulitic crystals.
,,	1½	Needle crystals become larger	Spherulitic and needle crystals.
900°	1	No crystals	Obscure.
,,	1½	,, ,,	Spherulitic and needle crystals.
,,	2	Needle crystals	Spherulitic and needle crystals become clear.
850°	1	No crystals	Crystals faintly visible.
,,	1½	Needle crystals	Spherulitic and needle crystals.
,,	2	Crystals well defined	,, ,, ,,
800°	1	No crystals	No crystals.
,,	1½	,, ,,	,, ,,
,,	2	,, ,,	Crystals faintly visible.
,,	3	,, ,,	,, better defined.
,,	3½	Indefinite	,, very clear.
,,	4	Crystals visible faintly	Become larger, with needle crystals.
,,	5	Needle crystals	,, ,, ,,
750°	2	No crystals	No crystals.
,,	2½	,, ,,	,, ,,
,,	3	,, ,,	,, ,,
,,	5	,, ,,	Crystals visible.
,,	10	,, ,,	Become larger.
,,	13	Faintly visible	,, ,,
,,	15	Needle crystals	,, ,,

Much longer time is required for the deposition of crystals when the glass is cooled from a high temperature, at which it is fluid, than when heated up from a low temperature. Thus, specimens of one glass (ST) were heated at temperatures (T_1°) between 1140° and 1170° for definite lengths of time as stated (t_1) and then cooled down and maintained at a lower temperature (T_2°) for a specified time (t_2). Results such as the following were obtained:

T_1°.	t_1 (min.).	T_2°.	t_2 (hours).	Result.
1140°	20	1000°	2	No crystals.
1140°	50	1000°	1	,, ,,
1150°	30	1000°	4	,, ,,
1150°	30	1000°	6½	Large laminated crystals.
1150°	25	800°	2	No crystals.
1160°	10	900°	½	,, ,,
1170°	30	900°	2	Needle crystals.

It will be noted that crystallisation under the above conditions took place with difficulty. On the other hand, when the glass was heated upwards, the devitrification appeared much quicker. Thus:

Temperature.	Time required for deposition of crystals. (minutes). S.I.A.	S.I.T.	S.I.M.
750°	15	3	3
800°	4	2	2
850°	2	2	2
900°	2	1½	1½
950°	1	1	1

From our experiments on sheet glass, it thus appears that spherulitic devitrification occurs at a temperature of 700°, is considerably more marked at a temperature of 800°, continuing to develop and assume more definite form as the temperature rises, the crystals finally melting or becoming redissolved at about 1100°. These facts are of interest and importance during the manufacture of sheet glass.

THE RESEARCH LABORATORY,
ASAHI GLASS CO., LTD.,
TOKIO, JAPAN.

XIX.—*Some Observations on the Mixing of Glass Batches in Factories.*

By A. W. DICKENSON, VIOLET DIMBLEBY, B.Sc., L. E. NORTON, B.Sc.Tech., and W. E. S. TURNER, D.Sc.

(*Read at the Sheffield Meeting, June* 21*st*, 1922).

THE observations recorded in this paper have, as indicated in the title, reference to actual glassworks practice. They do not represent the results of a systematic scientific study of all the factors on which batch mixing is dependent, since this was not possible under the conditions of observation; but being gleaned from factory procedure over a period of some years, they are of interest and probable value in indicating pitfalls and sources of error.

In the mixing of batch, several factors come into action either to militate against or to ensure successful results. It will not be difficult to understand that the actual sizes of the particles of the several ingredients may render the preparation of a homogeneous mixture quite impossible. Some manufacturers will recall that in this country, up to quite recent years, pieces of limestone as large as, or even much larger than, walnuts, were added to the batch in common bottle tank furnaces. Homogeneous batch, in the real sense of the word, is in such circumstances an impossibility.

The two commonest types of batch used in glass-making are the sand–soda ash–limestone (with perhaps salt-cake), and the sand–lead oxide–soda ash and/or potash. For the purpose of argument, the minor constituents may be neglected. Of these constituents, sand is never powdered, and it would be an uneconomical process, quite apart from the desirability of doing so, to crush it. The bulk of the particles should be of a size to lie on sieves between 30- and 70-mesh. Particles larger than 20-mesh should be excluded, whilst the fine material smaller than is retained by 100-mesh is undesirable on other grounds than are concerned with mixing. The soda ash when dry is in the form of powder very much finer than the sand. The limestone particles vary considerably in size. In some forms, especially in chalk and precipitated calcium carbonate, the particles are very small, often passing through a 200-mesh sieve. On the other hand, limestone chippings varying from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch, or even larger, are used in tank furnaces. Unless the limestone is carefully picked and treated at the quarry, it is quite wise to place a limit of $\frac{1}{8}$ inch size on the particles, since the very fine material is liable to contain an excessive quantity of dirt. Recently, superior preparations of granulated limestone or limespar have become available with particle size as small as 80-mesh, or with sizes varying very much over the same region as sand grains.

In the normal lead oxide batch, only the sand is granular, the other materials having fine particles (supposing the soda and potash to be really dry).

Now, other things being equal, the most thorough mixture would be expected when the particles are all of a size; and the use both of granulated limestone, as already mentioned, and of granulated soda ash, which is also coming on to the market, would seem to be a step in the right direction.

The use of hoppers for storing dry batch, suspended over the doghouse of a tank furnace, has at times been attended with the disadvantage that the sand grains tend to segregate and become richer at the bottom of the bin. Whilst this separation may occur slowly during the standing of the batch, it occurs to a greater extent as the latter is emptied into the bin, the sand grains falling somewhat more rapidly, the resistance of the atmosphere being less than towards the finely powdered soda ash or limespar.

Not only the difference of actual size or mass of the particles, but also the specific gravities or relative densities, influence the intimacy of mixing, as in the case of lead-oxide-containing batches. This effect is especially to be observed with thoroughly dried batch materials.

Clearly, also, the presence of moisture will influence the degree of thoroughness with which mixing takes place. It is not proposed to discuss the factor here, and, indeed, no systematic works observations were made, but it is easy to see that the adhesion of the grains caused by the presence of moisture may or may not be beneficial, according to the degree of wetness.

These various factors combine in producing the commercial results tabulated later.

The Weighing or Measuring of Batch Materials, and the Apparent Swelling of Sand when Wet.

In far too many works in this country the precise weighing out of each important batch constituent is still neglected, and quantities are more frequently measured by volume. Even when conscientiously done, errors are bound to creep in, and there are factors, especially the effect of varying moisture content, which the batch-mixer himself cannot allow for.

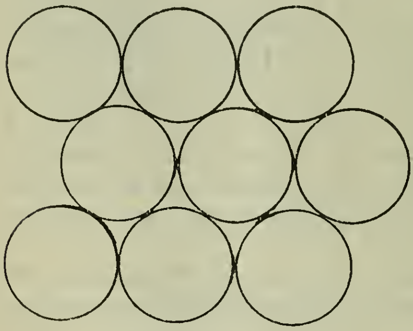


Fig. 1.

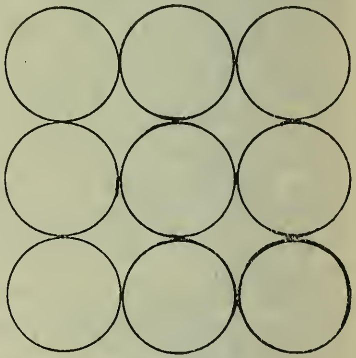


Fig. 2.

When a sand is dry it can be got into its form of closest packing by gentle shaking, the particles flowing one over the other to fill interstices. There is no difficulty, when care is used, in obtaining trustworthy measurements of sand by volume when the sand is perfectly dry. In a set of five experiments in which a glazed earthenware jar was filled with dry sand, we obtained as the weight completely filling the jar the following figures : 595·8 gm., 595·6 gm., 595·7 gm., 595·7 gm., and 591·3 gm. The extreme deviation from the mean does not amount to 0·5 per cent.

Osborne Reynolds * regarded the sand grains, when in their normal close packing, as occupying positions relative to one another as indicated in Fig. 1. When, however, pressure is applied, the configuration is distorted to that set out in Fig. 2, with the result that the total volume becomes increased. The effect of pressure in this connection was shown by Reynolds in an experiment in which an india-rubber bag was completely filled with sand; the outlet was then connected with a glass tube and sufficient water added to fill the space between the grains and to rise a short distance in the glass tube. When pressure was applied to the bag the water in the tube did not rise, as might be expected, but actually fell, showing that the available space between the grains had become greater.

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* *On an Inversion of Ideas as to the Structure of the Universe*, Cambridge, 1903.

The application of pressure to a damp sand in order to make it fill a certain space never results in squeezing the same weight of wet as of dry sand into that particular volume. An old-fashioned batch-mixer informed one of us that he obtained the same weight of sand by volume measurement, whether the sand were wet or dry. As a matter of fact, this is only true in the extreme case when the sand is filled into the measuring vessel dry and afterwards wetted in position. We have found that when a vessel is filled with dry sand and water added, the water is all absorbed without any apparent increase in volume.

If, however, a certain amount of dry sand which will fill a given vessel is emptied out and then wetted, it can no longer all be forced back into the vessel.

Quite a large number of experiments have been carried out by two of us independently on this point. Vessels varying in size from a weighing bottle to jars holding more than one pound have been used, and the same general result has been obtained in all cases.

In one method of test—and the results obtained from one method will be sufficient to demonstrate the point—a quantity of dry sand was filled into an earthenware jar with a tablespoon. After the addition of each spoonful the sand was levelled by raising the jar about an inch from the bench and allowing it to fall when the jar was about a quarter full. A glass cylinder slightly less than the earthenware vessel in diameter was placed on the surface of the sand and a 5 lb. weight laid on the top of the cylinder. The sand thus received a constant flattening pressure for each filling. More sand was filled in until the jar was half full and the weight again applied. In a similar manner, the jar was filled in four stages and the surface finally levelled off. After obtaining the weight of the dry sand contained by the jar filled in this manner, the sand was emptied into a mortar and well mixed with a definite amount of water. As much as possible of the damp sand was then charged into the jar in stages as before. In every case there was a large excess of sand. This was dried at 105°, cooled, and weighed.

In the tests, three different sands were employed, namely, Fontainebleau, Kilconquhar, and Tentsmuir. The first, as is well known, contains approximately 99·5 per cent. of silica; the last-named contains more than 8 per cent. of alumina.

Tables I and II show the result of these tests, the former stating the results of duplicate tests to indicate the sort of agreement possible, the second giving the average value.

TABLE I.

The Apparent Percentage Increase in Volume on Wetting.

	Percentage Moisture in the Sand.			
Sand.	2·5.	5.	7·5.	10.
Fontainebleau	15·50	14·66	14·85	14·42
,,	16·60	16·30	16·99	16·17
Kilconquhar	12·44	14·75	15·23	14·65
,,	12·93	14·52	14·74	14·30
Tentsmuir	16·26	17·15	17·94	17·29
,,	14·50	19·04	18·54	18·20

TABLE II.

Mean Values. Apparent Percentage Increase in Volume.

	Percentage Moisture in the Sand.					
Sand.	1.	2.	2·5.	5.	7·5.	10.
Fontainebleau	13·71	14·24	14·86	15·51	15·85	15·34
Kilconquhar	5·97	10·23	12·78	14·13	13·87	13·25
Tentsmuir	10·42	15·00	15·26	18·21	17·91	17·74

The term "apparent increase in volume" referred to in the tables was measured by determining the excess of sand (after drying) which could not be forced back into the jar when wet. The excess of sand will be seen to be large, and it does not vary very greatly with variation of moisture content, so far as tested.

It might therefore be thought that in practice the error involved would not be very great, since the sand in many factories contains 2 per cent. of moisture, and variation in the moisture content does not cause much variation in the ease or difficulty of packing. The error, however, is quite considerable; for, although a barrow may have been calibrated by the use of damp sand, it does not follow that in charging in another quantity of damp sand precisely the same amount will be obtained, owing to the resistance which the wet sand offers to adjustment in its packing.

As a matter of fact, one of us has in two different works at various times had barrows of sand weighed. The barrows were supposed to hold a fixed amount, and although they were filled by a quite conscientious workman, they were found in all cases to deviate from the correct weight to the extent of 20 to 30 lb. per thousand.

This amount is quite sufficient to alter the working properties of the glass made, and it must be definitely laid down as a rule that the only satisfactory method of making up a batch with precision is to weigh out the sand and to make allowance for the moisture which it contains after the determination of that moisture in a sample.

The Results of some Factory Tests.

After the preceding discussion of certain principles underlying the mixing of the batch, it will be of interest to state the results of some investigations of actual works batches.

Samples of ten batches were taken from eight different works. Nine of the batches were for producing soda–lime glasses and one for a soda–lead oxide glass.

Again, five of them were mixed, in the main, by hand, and in the case of the other five by machine.

The plan adopted was to take three samples from different portions of the same batch, the amount of the sample varying from about ½ lb. to 2 lb. Each sample of each batch was carefully sifted so as to ascertain what sizes of particles made up the bulk and a simple chemical analysis of the constituents was next made. This chemical analysis usually took the form of a determination of the total insoluble matter (practically always sand), the calcium oxide, and, in most cases, the total carbon dioxide (resulting both from the soda ash and the limestone or limespar). The following tables record the results :

Batch I.

Hand-mixed, using sand, slaked lime, and soda ash. Four samples were taken.

	Percentage of Grains of Different Sizes. Sample.			
Left on Mesh.	1.	2.	3.	4.
10	9·9	11·2	23·4	6·2
16	1·3	9·0	7·0	1·6
20	1·0	7·9	5·2	1·0
30	7·9	26·5	12·4	10·4
40	11·6	8·2	5·7	12·9
50	39·1	6·6	9·7	42·4
60	12·1	3·3	9·7	12·5
70	8·2	6·6	16·9	7·0
100	6·4	14·6	9·0	5·2
120	1·3	2·0	0·8	0·7
Through 120	1·0	4·0	0·3	0·3

	Percentage Chemical Composition.			
	1.	2.	3.	4.
Insoluble	59·48	72·39	44·02	77·07
Lime (CaO)	8·34	4·78	5·72	6·96

The heap of batch when cut through showed an almost stratified appearance, and was obviously far from mixed. Some lumps of lime were found which were only imperfectly slaked. No two samples had anything like the same composition, either chemically or in grain size.

Batch II.

Hand-mixed on the floor and subsequently carried by a bucket conveyor to the glasshouse floor. Sand, soda ash, salt-cake, and limestone chippings were used, all fairly dry. Three samples taken.

Percentage of Grains of Different Sizes.

Mesh of Sieve.	Sample.					
	1.	Remarks.	2.	Remarks.	3.	Remarks.
10	25·2	Sand and lime chips.	28·1	Sand, lime chips, and soda ash.	26·7	Sand, lime chips, and soda ash.
16	5·0	,,	4·3	,,	4·4	,,
20	1·8	,,	2·7	,,	1·9	,,
30	11·9	Mostly sand, some lime chips.	10·81	Sand and lime.	9·2	Sand and lime.
40	10·1	Sand.	9·7	Sand.	8·2	Sand.
50	22·0	,,	18·9	,,	30·2	,,
60	5·4	Sand and lime.	5·4	Sand and lime.	4·8	Sand and lime.
70	13·0	,,	9·2		8·3	
100	4·7		8·1		5·3	
120	0·8		1·1		0·5	
$<$120	0·8		1·6		0·5	

	Percentage Chemical Composition.		
	1.	2.	3.
Insoluble	52·85	55·84	59·53
Lime (CaO)	9·96	7·50	7·48
Total CO_2	7·26	6·50	4·98

The large portion of the batch retained on 10-mesh was due to the use of limestone chippings, but some large sand grains and caked soda ash were also present. The three samples show no very great differences in the grading, but the chemical compositions deviate considerably.

Batch III.

Hand mixed and prepared in manner similar to II but contained less salt-cake and proportionately more soda ash.

Percentage of Grains of Different Sizes.

Mesh of Sieve.	Sample. 1.	Remarks.	2.	Remarks.	3.	Remarks.
10	20·0	Lime chips.	19·5	Lime chips.	25·6	Lime.
16	4·2	"	4·4	"	3·8	"
20	2·1	Mostly sand.	2·8	Sand.	1·5	Sand and lime.
30	11·2	"	7·8	"	9·0	"
40	11·8	Sand.	22·9	"	14·3	Sand.
50	21·5	"	13·9	"	11·3	"
60	7·9		12·2		11·3	
70	12·4		11·1		12·8	
100	7·9		4·4		3·8	
120	0·6		0·5		2·6	
<120	0·3		0·5		1·1	

Percentage Chemical Composition.

	1.	2.	3.
Insoluble	64·56	63·71	51·94
Lime (CaO)	7·66	7·04	10·54
Total CO_2	7·97	8·84	8·21

The grading is not nearly so regular as in Batch II, and whilst the chemical compositions of samples I and II are somewhat similar, that of sample III is widely different.

Batch IV.

Hand-mixed, being turned over three times on floor. Sand, soda ash, and powdered chalk used, the sand and chalk being wet when the batch was mixed.

Percentage of Grains of Different Sizes.

Mesh of Sieve.	Sample. 1.	Remarks.	2.	Remarks.	3.	Remarks.
10	15·2	Limestone and caked soda ash.	21·5	Limestone and caked soda ash.	26·2	Limestone and caked soda ash.
16	8·1	"	9·3	"	10·5	"
20	10·4	"	7·0	"	7·5	"
30	20·4	Sand, lime, and soda.	19·2	Sand, lime, and soda.	25·9	Sand, lime, and soda.
40	11·8	Mostly sand.	8·4	Mostly sand.	7·5	Mostly sand.
50	16·6	"	15·0	"	8·8	"
60	10·4	Sand and soda.	11·2	"	7·9	"
70	4·7	"	4·6	Sand and soda.	3·1	Soda and lime.
100	1·4	Soda.	2·3	Soda and lime.	1·8	"
120	0·5	"	0·9	"	0·4	"
<120	0·5	"	0·5	"	0·4	"

Percentage Chemical Composition.

	1.	2.	3.
Insoluble	72·24	57·83	58·35
Lime (CaO)	4·84	7·54	5·28
Magnesia (MgO)	1·37	2·07	0·34
Total CO_2	9·63	14·61	15·53

The effect of the moisture was seen in the caking and balling up of the soda ash and the calcium carbonate, the lumps of which were retained on the sieves up to 20-mesh. The chemical compositions were most irregular.

Batch V.

Hand-mixed, being turned over twice on the floor, elevated in a tub, and dumped on the glasshouse floor. The batch contained sand, soda ash, salt-cake, and limestone chippings. Six samples were taken, three from the heap immediately after mixing and three others after the batch was transferred to the glasshouse floor.

Percentage of Different Sizes of Particles.

	From Mixing Room.			From Glasshouse.		
Mesh of Sieve.	1.	2.	3.	1.	2.	3.
10	19·0	11·9	16·3	16·8	18·6	20·8
16	2·4	2·1	1·9	1·5	1·7	2·0
20	1·1	0·9	1·1	1·1	0·8	0·9
30	2·4	3·4	1·8	1·1	2·4	2·1
40	21·6	13·3	35·0	7·3	16·4	4·0
50	33·6	49·8	10·9	25·8	13·0	16·0
60	9·2	6·2	9·4	25·4	17·2	17·8
70	4·1	4·7	14·0	13·7	17·5	19·2
100	2·4	6·1	7·1	5·3	7·3	11·9
120	2·1	1·1	1·6	1·2	2·0	3·0
<120	2·1	1·2	1·4	1·0	2·9	2·6

Percentage Chemical Composition.

	1.	2.	3.	1.	2.	3.
Insoluble............	57·85	62·43	66·12	66·04	57·84	55·84
Lime (CaO)	9·84	6·72	8·86	6·62	8·66	10·36

Both the grading and the compositions were irregular.

Batch VI.

Mixed in a Gardner machine mixer, using sand, soda ash, and precipitated chalk. Materials fairly dry.

Percentage of Different Sizes of Particles.
Sample.

Mesh of Sieve.	1.	Remarks.	2.	Remarks.	3.	Remarks.
10	0·9	Caked soda.	1·61	Caked soda.	3·0	Caked soda.
16	0·7	,,	0·5	,,	0·9	,,
20	0·2	,,	0·5	,,	0·4	,,
30	1·5	Soda and sand.	1·8	Mostly sand.	4·5	Mostly sand.
40	7·8	Sand and little soda.	8·7	,,	12·0	,,
50	40·8	Mostly sand.	37·2	,,	34·3	,,
60	5·8	Sand.	9·2	,,	26·8	Sand, lime and soda.
70	23·5	Soda and lime.	21·2	Soda and lime.	15·1	Soda and lime.
100	13·3	,,	15·6	,,	1·7	,,
120	0·7	,,	0·5	,,	0·4	,,
<120	4·8	,,	3·2	,,	0·9	,,

	Percentage Chemical Composition.		
	1.	2.	3.
Insoluble	62·59	63·33	61·65
Lime (CaO)	6·11	4·91	4·99
Total CO_2	13·2	13·09	13·15

Batch VII.

Mixed in Gardner mixer for ten minutes. Sand, slaked lime, soda ash, and potash as batch materials. Dried sand used.

Percentage of Different Sizes of Particles.

Mesh of Sieve.	Sample. 1.	Remarks.	2.	Remarks.	3.	Remarks.
10	1·6	Lime fragments and soda ash.	2·5	Lime fragments and soda ash.	1·8	Lime fragments and soda ash.
16	3·9	Mostly lime.	4·1	Mostly lime.	3·9	Mostly lime.
20	5·4	,,	5·6	,,	5·4	,,
30	64·7	Sand, soda, and lime.	75·9	Sand, soda, and lime.	66·2	Sand, soda, and lime.
40	9·1	,,	8·7	,,	6·4	,,
50	10·2	,,	1·0	,,	11·4	,,
60	1·3	Soda and lime.	0·5	Soda and lime.	1·3	A little sand, soda, and lime.
70	1·0	,,	0·8	,,	1·8	,,
100	1·0	,,	0·5	,,	1·1	,,
120	0·3	,,	0·3	,,	0·3	Soda and lime.
<120	0·3	,,	0·1	,,	0·5	,,

	Percentage Chemical Composition		
	1.	2.	3.
Insoluble	67·35	66·49	68·39
Lime (CaO)	5·96	6·17	5·66
Total CO_2	11·21	11·61	11·24

Batch VIII.

Lead oxide batch, mixed in Gardner mixer for ten minutes. Sand, red lead, lime, and soda ash used, all dry.

Percentage of Different Sizes of Particles.

Mesh of Sieve.	Sample. 1.	Remarks.	2.	Remarks.	3.	Remarks.
10	3·3	Soda ash.	3·3	Soda ash.	4·2	Soda ash.
16	3·3	,,	3·6	,,	2·8	,,
20	4·5	,,	3·0	,,	3·7	,,
30	12·8	Sand and soda ash.	9·2	Sand and soda ash.	11·2	Sand and soda ash.
40	35·6	Sand.	27·8	Sand.	33·6	Sand.
50	24·2	,,	35·9	,,	28·2	,,
60	6·5	Sand and soda ash.	8·5	Sand and soda ash.	7·0	Sand and soda ash.
70	4·9	Soda ash.	4·1	Soda ash.	4·2	Mostly soda ash and red lead.
100	3·3	,,	2·6	,,	2·8	Soda ash and red lead.
120	0·7	,,	1·3	,,	0·7	,,
<120	0·7	,,	0·7	,,	1·4	,,

	Percentage Chemical Composition.		
	1.	2.	3.
Insoluble	61·39	59·89	60·3
Lead oxide (PbO)	15·38	16·51	15·16
Lime (CaO)	1·05	1·11	1·93

Batch IX.

Machine-mixed in the Smith mixer, the batch being of sand, granulated limespar, and soda ash. The first sample was taken at the beginning of the discharge after mixing, the second after half was discharged, and the third when the mixer was nearly empty.

	Percentage of Different Sizes of Particles. Sample.		
Mesh of Sieve.	1.	2.	3.
10	2·4	2·5	2·0
16	2·4	3·5	3·8
20	1·2	2·0	1·5
30	3·6	5·0	5·8
40	23·0	22·5	18·8
50	19·8	21·7	32·5
60	16·2	14·0	9·0
70	9·0	7·5	6·0
100	18·0	13·2	11·0
120	4·0	4·5	6·5
<120	1·0	4·2	2·8

	Percentage Chemical Composition.		
	1.	2.	3.
Insoluble	62·28	62·20	62·18
Fe_2O_3 and Al_2O_3	0·15	0·10	0·15
CaO	5·82	8·10	8·94

The distribution of the sand (or the insoluble) in this batch was remarkably uniform. The lime distribution was less satisfactory.

Batch X.

Machine-mixed in Stothert Pitt mixer, for about two minutes. Sand, soda ash, and crushed (granulated) limespar were used. The mechanical analysis was complicated by the fact that the cullet was added to the batch in the mixer. Much of this cullet was separated on the 10–20-mesh sieves, although some still smaller pieces passed through, constituting the "residual" cullet of the table below. There is little point, therefore, in quoting the mechanical analysis.

	Percentage Chemical Composition.		
	1.	2.	3.
Insoluble (including residual cullet)	69·06	73·78	73·13
Lime (CaO)	6·62	4·22	4·35
Total CO_2	8·54	8·44	8·61

The results are worth close study. Attention has already been directed to the diminished efficiency of the mixing when limestone chippings were used. A good, second grade limestone in a granulated form for tank furnace work would be a great advantage instead of chippings. First grade material for colourless glass is already available.

Unfortunately, the hand-mixed batches, except No. IV, all contained limestone chippings, whilst the machine batches had the limestone in either a granular or a finely divided state. Strict comparison is therefore not possible.

We are quite convinced that, given intelligence, time, and fairly dry materials, which are either granular or powdered, thorough mixing can be obtained by hand. Unfortunately, in practice, all these conditions do not exist. Frequently the mixer for a tank furnace has more work to do than he can thoroughly cope with if he is to keep the furnace or furnaces supplied with batch. Certainly all the hand-mixed batches described above leave much to be desired. No. I obviously cannot be described as mixed. But in all the four other cases, no two samples drawn from the same batch agree at all closely in composition, one constituent being either in considerable excess or insufficient. Moreover, the total carbon dioxide varies greatly, showing that an excess of lime is not counterbalanced by a diminished amount of soda ash, and *vice versa*. Indeed, there is no regularity to be observed. It will also be noted that Batch V has not been materially improved by transference to the glasshouse floor.

The factories which use a machine mixer clearly obtain far more homogeneous batches. This is demonstrated by the results for all the machine-mixed batches. The distribution of the sand through the several samples is quite good. In batch No. IX it is, indeed, very good. In batch No. VII, the lime in the form of slaked lime is fairly well distributed, but a curious effect is to be noted in all the other machine-mixed batches. Two out of the three samples of each batch agree quite closely in regard to the lime content, but the third either contains a big excess or contains much less than the others. It is of special interest to note that the sample which shows this excess or deficiency is the first sample which comes from the machine, and it would clearly indicate that perfection in machine-mixing is not yet attained.

It is of interest to note, however, that the total carbon dioxide derived both from the soda ash and the limestone is practically the same in all three samples of each batch. The particular sample, therefore, which contains either an excess or a deficiency of lime must contain a corresponding deficiency or excess of soda ash.

The sand, as has been pointed out, appears to get distributed fairly uniformly.

It does not seem possible from the results to advocate one type of mixer over another in so far as the efficiency of mixing is concerned. Tests with the same type of material, mixed for the same length of time, would have to be carried out in order to arrive at a satisfactory comparison. What can definitely be stated, however, is that manufacturers who mix their batch by a machine undoubtedly achieve better results than those who are content to have the batch mixed by hand. It is not a question of what is possible by hand, but what is attainable under works conditions, and under such conditions we have demonstrated that hand-mixing falls below modern requirements. The best mixed batch is the one which will melt most readily and cause least difficulty in producing cords, stones, or other defects from which glass from time to time suffers.

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Discussion.

Mr. W. J. Rees said he wished to congratulate the authors on the novel investigation, especially in regard to the sand tests. The results were of extreme interest, but one hesitated to accept them as, well, to put it broadly, gospel. If one got such enormous expansions on wetting sands, why were there not also enormous alterations in sandy districts after rain-storms? One knew there were small changes in the volume of sand, but such enormous expansions were extraordinary.

Mr. J. H. Davidson said he had come across a great deal of trouble when measuring batch by the crude method of barrows. The method could be carried out fairly accurately, but it took a lot of looking after. He should say that the apparent swelling of sand, when the moisture varied by about 1 per cent., did not affect many people in a glassworks, as it was noticeable from the figures given by the authors that there was not much variation in the volume when the moisture content ranged between 2 and 5 per cent., which was what one usually found in sand stored for any considerable period of time. Did not the question of grain size come in? He had found a difference of plus or minus 15 pounds in 20 stones, according as the sand was Belgian or Lynn, or a mixture of the two. Greater variation had been found by him on account of the grain size than the moisture when measuring the sand by volume. One could control the moisture if the grain size were constant.

Dr. Bain thought it was not so much the grain size that mattered in packing, but the angularity. If one had various types of surfaces the frictional effect due to moisture would be different. He considered that the case studied by the authors, of the effect of moisture on the volume of sand, was not one of expansion but of close packing.

Mr. H. W. Howes asked if different results were obtained according as the sand was pure or impure.

Mr. F. J. Boam stated he had found that with sand of irregular grain one could get a much bigger weight in a given receptacle than with sand of regular grain size. From certain experiments he had made, he did not think that sand swelled very much with water.

Mr. Guy Simpson was inclined to think that the results obtained by the authors in their tests on the effect of moisture on sand were due to experimental errors, consequent on untrustworthy methods.

Mr. W. Butterworth, jun., asked if any attempt had been made to use the same size of grain in the sand under test with water.

Mr. P. Haller pointed out that, in the tests on the sand, the latter was pressed down in the jar by a 5-lb. weight. As Osborne Reynolds had shown, pressure on sand altered its normal packing and caused an increase in the volume occupied.

Mr. L. E. Norton agreed that the term "expansion" was wrong. In one experiment made, a jar was filled with dry sand and moisture added gradually at the surface. At first, there was a marked expansion, but when the sand was thoroughly wet the initial swelling subsided again. That might explain why there were no upheavals in sandy districts. A spoon was employed in charging the jar, partly because it helped the packing and partly because in works it seemed to be the custom if the sand was at all wet to bat it down with a spade, thus applying pressure. In regard to the effect of grain size, work was begun on different sized gradings of Fontainebleau sand, but the tests had not been completed.

Mr. J. H. Davidson said he would like to ask if it was fair to compare the mixing by machine with the mixing by hand, seeing that in the one case the materials were probably measured by barrow and in the other case weighed. He also said that he himself had found very considerable difficulty in getting concordance in the analyses of samples of batch. He often obtained better results by taking a small sample of the batch than a larger quantity.

Mr. M. Parkin said he could confirm Mr. Davidson's statement in regard to obtaining better results with smaller samples than with large.

Mr. J. H. Davidson stated that he thought probably the difficulty of obtaining good samples was dependent on the amount of moisture in the batch and that a more uniform sample was obtained from a slightly damp batch.

Dr. M. W. Travers (*communicated*) said he thought that the most efficient mixing plant would consist of a set of crusher rolls mounted over a paddle or cone mixer. The sand would be run from one bin into the mixer, and the soda ash, lime, etc., would run from another bin through the crusher rolls. The feeding should be such that the materials ran on to the mixer at proportional rates.

Prof. W. E. S. Turner, in reply, said that the discussion on the subject had been exceedingly keen and satisfactory. In some ways, indeed, it had not been a disadvantage that a somewhat incorrect impression had been given by the use of the term "apparent swelling" of sand, as undoubtedly this term had served as a challenge to members of the audience. He thought the detailed account in the paper itself would indicate that the difficulty really existed in the packing of the sand when wet. He would like if possible that the result which had been stated that afternoon should be considered as a further challenge to members of the audience and manufacturers in general to test their methods of weighing and measuring in order to ascertain actually what percentage of error it involved in the mixing of the batch. He thought some of them would be surprised at the results obtained. Such a series of tests would afford a very simple introduction to methods of research in the glasshouse, and once started might be pursued along other avenues outside batch mixing.

In reply to Mr. Davidson's remarks, questioning the possibility of comparing the hand-mixed and machine-mixed batches described, he would point out that the question of weighing or of measuring did not enter into the problem at all. The test that was made was wholly one of homogeneity of the batch, so that it did not matter whether the materials were weighed or measured. As a matter of fact, in two of the batches mixed by hand, the materials were weighed and not measured.

XX.—*The Development of Coloured Glass in England.*

By (the late) HARRY J. POWELL, C.B.E., B.A.

(*Read at the York Meeting, October* 18*th*, 1922.)

COLOURED glass suggests stained and painted windows, but serves many other purposes. It is used for making and decorating table-ware, for vases, for shades for gas, oil, and electric light; for signalling; for shades and light-filters in photography; for imitating gems; for jewellery; for medical tests; for spectacles, and if opaque glass be included, for covering floors, walls, and ceilings with mosaic.

The first making of coloured glass was probably accidental.

It is difficult to give even an approximate date for the intentional manufacture of coloured glass in England. Benedict Biscop is said to have imported one or more glass-makers from Gaul, in 675, to glaze the windows of his church at Wearmouth and to teach the art to Englishmen. There is, however, no record of any result, and, if the glass was made, it was probably not intentionally coloured. English glass-makers would most gladly claim for their predecessors the gem-like glass of the twelfth and thirteenth century windows, and parts of windows, which have survived in York Minster, the cathedrals of Canterbury and Lincoln, and elsewhere, but there is no proof on which the claim can be based. These windows in technique and in the tints and texture of the glass so closely resemble windows of similar date in the French cathedrals of St. Denis and Chartres that they must be attributed to the same source, and it is impossible to suggest that the glass in the French cathedrals was made in England. As in the case of Wearmouth church, glass-workers may have been sent from France to make the glass and paint the windows in England, but it is more probable that the glass was imported.

Britton, in his "History of Exeter Cathedral," records the import from Rouen of a large quantity of glass for the cathedral between 1303 and 1317. Winston * says: "I have been much struck with the purity and hardness of the Exeter glass," qualities also noticeable in the "early decorated" glass in Westminster Abbey and in the chapel of Merton College, Oxford.

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* "Art of Glass Painting," p. 171.

The Exchequer Rolls of Edward III, 1352, give the first trustworthy evidence of glass being made for windows in mediæval England, but it is doubtful whether the evidence refers to coloured as well as to colourless glass. Edward III had requisitioned glaziers and glass for St. Stephen's Chapel,* Westminster. John Alemayne (de Alemayne), a glass-maker in Chiddingfold, Surrey, supplied several consignments of glass through W. Holmere of Candlewick Street in the city, who acted as agent and carrier. The glass specially sent from Chiddingfold was colourless, but Holmere supplied azure glass from some other source, probably from abroad. Coloured glasses were also obtained from other agents; red from Henry Staverne, blue from Leuen Crawe, and white and other colours from John Prentis.

The fabric rolls of Durham Cathedral record the purchase of 100 lb. of English glass in 1399, but it is not stated whether coloured or colourless, or whence obtained. The rolls of York Minster contain entries of purchases of glass by successive master-glaziers from 1418 to 1536. Robert Yarndon bought white glass from John Glasman of Rugeley, Staffordshire, in 1418; Matthew Petty in 1457 bought glass of diverse colours, *vitrum diversi coloris*, from an agent in Hull, Peter Faudkent, and in 1536 William Matthewson, also of Hull, supplied 21 wyspes of Burgundy glass, coloured and white. It appears that in mediæval times Burgundy glass, that is, broad- or sheet-glass, plain and coloured, was imported *via* Antwerp and Hull, whilst Normandy crown-glass was exported from Rouen to English ports on the south and west coasts.

In 1447, John Prudde, glazier of Westminster, contracted to glaze all the windows in the "new Chappell in Warwick (Beauchamp Chapel) with glasse beyond the seas and with no glasse of England and in the finest wise, with the best, cleanest and strongest glasse beyond the seas that may be had in England and of the finest colours of blew, yellow, red, purpure, sanguine and violet."

It has been suggested that the clause in the contract for the windows in the Beauchamp Chapel, forbidding the use of English glass, and implying that the manufacture, if in existence, was in an unsatisfactory condition, was due to some mistake. But in the licence granted in 1449 by Henry VI to John Utynam, it is definitely stated that the art of making coloured glasses has never been used in England, and it must be remembered that this statement was made by the grantor, not by the grantee. The licence was to enable Utynam,

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* In 1800, when the House of Commons was enlarged, some of the glass of St. Stephen's Chapel was found *in situ*; there were specimens of amber, two blues, green, pink, ruby, and violet.

> "born in Flanders but returned to England by the King's command, to settle with his family and become the King's liege, in order to make glass of all colours for the windows of the Chapels of Eton College and of the College of St. Mary and St. Nicholas in Cambridge." *

Whether Utynam settled in England and made coloured glasses for Eton and King's College, Cambridge, is unknown. The few remains of fifteenth-century painted glass in King's Chapel appear to have come from some other building.

In the contract entered into in 1526 between Robert Hacomblyn, D.D., provost of King's College, Cambridge, and Galyon Hoone, glazier, "of the paryshe of Seint Mary Magdalen, next St. Mary Overy in Suthwerke," and others, for glazing eighteen windows of the college "with good, clene, sure and perfyte glass and oryent colors, all the seid wyndowes to be bound with double bands of lead for defence of great wyndes and outrageous wetheringes," the word Normandy before the word glass has been erased. The erasure may mean either that "Burgundy" or Flemish glass was to be substituted for Normandy glass or that good English coloured glass was at last obtainable.

Reference to the "books of rates" which record the duties charged on goods imported from abroad proves that both "Normandy" and "Burgundy" glasses, white and coloured, were imported in considerable quantity, certainly to the end of the seventeenth century. The importation of Flemish glass must have been stimulated by the coming to England of Bernard van Linge, the glass-painter, early in the century, and the gradual replacement of the use of transparent coloured glass by the use of enamel paints would not encourage the development of the home manufacture of coloured glasses.

Bernard van Linge's famous east window in Wadham Chapel, Oxford, dated 1622, shows the well-balanced use of coloured glass and coloured enamel, but the windows of Abraham van Linge and of the English glass-painters who followed him, illustrate the gradual decrease in the use of coloured glass and the increase in the use of enamels.

The master glazier was succeeded by the enamel-painter and the effects of enamel painting can be judged by the works of the Prices of Hatton Garden, of William Peckitt of York (1731—1795), of Francis Egginton of Birmingham (1737—1805), of Pearson, who painted the window in Salisbury Cathedral (designed by Mortimer), representing Moses uplifting the brazen serpent, and of Thomas

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* Calendar of Patent Rolls: Henry VI, 1446–52.

Jervais, who, in 1782, painted the west window of New College Chapel, Oxford, designed by Sir Joshua Reynolds. This window in recent years has been cased with sheet-glass in the hope that the complete destruction of Jervais's enamel-paints may be temporarily postponed.

The decay of enamel-paints has been almost invariably due to the presence of borax in the mixtures. Borax causes an enamel to fuse easily and smoothly, but being readily attacked by moisture gradually dissolves out and the paint disintegrates.

From time to time interest has been aroused on the subject of the decay of the actual substance of mediæval window-glass. "Archæologia," November 30th, 1872, contains a full and accurate description by James Fowler, F.S.A., of the various forms of decay in ancient glass. It must not be assumed that decay is necessary. Many pieces of ancient Roman glass show no signs of it and a great deal of twelfth- and thirteenth-century window-glass is perfectly sound or merely superficially roughened and pitted. Some mediæval glass, however, has become partly or wholly opaque and is so completely disintegrated as to crumble to powder. The most defective glass belongs to the fourteenth century and the condition of some of the fourteenth-century windows in York Minster first directed serious attention to the subject of decay. It is known that a large proportion of the glass used in the Minster is Flemish, and it would be interesting to ascertain whether the Flemish glass is more liable to decay than the Norman. There are many different forms or stages of decay, but all have originated from an excessive proportion of alkali in the glass mixture which has caused the glass to be hygroscopic. Considering the haphazard way in which alkali was added to the glass mixture by mediæval glass-makers, it is more remarkable that a large proportion of mediæval glass has survived than that a small proportion has failed.

Decay is not unknown in modern glass. A few years ago it was feared that the fourteenth-century windows in the Latin Chapel of Oxford Cathedral were perishing. After a careful examination it was found that the genuine fourteenth-century glass was perfectly sound, but that some imitation fourteenth-century glass used to patch the window early in the last century had perished hopelessly. The author has examined two specimens of glass certainly less than fifty years old which crumbled to fragments through decay: one was a virulent green glass, coloured with oxide of chromium, in which crystallisation had taken place, the other a pure, colourless, potash-lime glass which was highly hygroscopic.

The first definite information about the making of coloured glass in England is to be found in Dr. Pococke's "Travels Through

England": "1751, 8 June, came to Stourbridge famous for its glass manufacture which is here coloured in the liquid of all the capital colours, in their several shades, and if I mistake not is a secret which they have here."

It is, however, doubtful whether any genuine copper-ruby glass was made either in Stourbridge or abroad during the eighteenth century. The art of making it seems to have been temporarily lost, and to take its place recourse was had to the use of a strong orange-coloured silver stain, the effect often being intensified by a wash of red or pink enamel. There is a specification for a patent for making transparent red glass, dated December 5th, 1755. The applicant proposes to obtain the colour by melting flint-glass with an equal quantity of "braunstein" and adding twenty grains of dissolved Dutch gold. "Dutch gold" is an alloy of copper with zinc, and "braunstein" is an impure oxide of manganese. The colour, if colour there was, was probably a purple due to manganese, and not ruby.

The credit of re-discovering the old method of making copper-ruby glass is attributed to Georges Bontemps, glass-manufacturer, of Choisy-le-Roi, in or about the year 1826. The tradition of making coloured glasses must have lingered in the Stourbridge district, for in the great Exhibition of 1851 coloured sheet-glass was exhibited by Chance Brothers of Spon Lane and by Lloyd and Summerfield of Birmingham. The manufacture of coloured sheet-glass by Chance Brothers dates from 1837, when they produced a green pot-metal glass and glasses stained lemon-yellow and red.

In 1848 Georges Bontemps took charge of the coloured glass department at Spon Lane. In 1857 the new copper-ruby sheet-glass was made for the first time. This glass could be re-heated for painted decoration without losing its colour, a defect of the copper-ruby previously made. The list of colours in 1857 included purple, yellow, yellowish-green, signal green, several shades of blue and a flashed opal. Gold-ruby sheet-glass was a later development. Painted glass windows were shown at the Exhibitions of 1851 and 1862. *The Illustrated London News* in June 1851, mentions Messrs. Chance's green glasses as "pre-eminent for brightness and transparency." The jurors of the 1862 Exhibition considered Chance Bros.' coloured glass "better than the foreign which has a dead appearance and looks stringy and smeared." In 1867 the painted glass department was given up. In 1873 the manufacture of antique coloured glass was transferred to the Oldbury works. The making, however, of lightly tinted "cathedral," "figured" and "muffled" glasses was continued and developed, as well as of signal green glass and flashed ruby glass for signal lamps. In the late 'sixties Chance Bros. obtained certain coloured glasses, including gold-ruby, yellow-green, and opal, from George Wood of Birmingham, who had been associated with Lloyd and Summerfield for many years. From 1870 to 1873 George Wood worked for Chance Bros. at the Spon Lane works. Alfred Wood, son of George Wood, joined James and William Hartley of the Wear Glassworks, Sunderland, in 1891. In 1892, when the Wear Glassworks were closed, James Hartley and Alfred Wood started the manufacture of antique coloured glasses at the Portobello Works, which have won a name for glasses of fine quality.

In London, improvements in the manufacture of coloured glasses for mosaic windows were due to the enthusiasm of an amateur. Charles Winston, barrister and archæologist, devoted his spare time to the accurate study of ancient painted glass with the view of finding the cause of the failure of modern reproductions, and a sure basis for the revival of the art of glass painting. He applied himself to the examination and comparison of specimens of old glass, to chemical analysis, and to the manufacture on an experimental scale of various colours from recipes preserved in the treatise of Theophilus. His researches convinced him that the beauty of ancient painted glass depended as much at least on the quality of the material as upon the skill of the artist. Writing from the Temple in 1856 he said,

> "ever since 1850 I have been amusing myself, at no small cost, in having analyses made of ancient glass, and have succeeded in discovering its manufacture. I gave the analyses to a glass manufacturer in this neighbourhood and with my scientific friends assisted him in reproducing the ancient material. I had first offered the analyses to Chance of Birmingham, if he would work them out, but he refused, and this was fortunate, as I should not have been able to attend to the experiments as much as I did. The colours we have made are blue, the streaky ruby, several, but not all, kinds of green, yellow, white and a few shades of purple. The new material is as harmonious in colour, brilliant and at the same time solid in appearance as the old glass."

The "Winston" antique glasses were shown in the Exhibition of 1862 and were described as similar to the coloured glasses of the thirteenth and fourteenth centuries. They possessed the solid effect of ancient glass, without the surface being subjected to any mechanical treatment.

The effect of the "Winston" glasses can best be seen in the St. Frideswide's window in the Latin Chapel at Christ Church, Oxford, and in the Jesse window in Waltham Abbey, both put up in the sixties of last century.

The same works in which Winston's experiments were carried out have continued to produce a long series of coloured glasses for church windows. One of the most successful has been a "brown" ruby, formed by successive casings of manganese purple and gold-ruby on an antique white base. About 1880, E. J. Prior introduced a method of making small rectangular panes of coloured glass, by blowing it into an oblong iron mould. The base and sides of the oblong-shaped bulb form the panes, which, owing to the "ruffling" effect of the surface of the mould, have a brilliant effect.

The effects of the later glasses can be seen in the windows of Liverpool Cathedral, and of the Cathedral of St. John the Divine, New York.

In America, about 1880, a system was introduced of using molten opalescent glass as a basis for coloured glass, and incorporating into the sheets streaks of various coloured glasses by pouring and rolling.

By this means, it was supposed that effects could be obtained, without the intervention of the painter, of moonlight, sunset, foliage, and drapery. The results, however, are more allied to the achievements of confectionery than of glass-making, and the external effect of the white slab of opalescent glass seriously affects the architectural beauty of a building, seen from the outside.

80, Alleyn Road,
Dulwich, London, S.E.21.

XXI.—*Processes and Methods of Mediæval Glass Painting.*

By J. A. Knowles.

(*Read at the York Meeting, October* 18*th*, 1922.)

This paper is written solely from the point of view of a glass-painter and an antiquary; for I can lay no claim to scientific knowledge or practical experience in glass-making. All I can do is to present some notes gathered together whilst engaged in the study and the restoration of ancient windows during a number of years and to invite discussion on them. Any explanations of chemical or scientific phenomena given in the course of the address must be taken merely as attempts to illustrate the point at issue rather than to represent exact scientific facts.

The King Charles's head of all lecturers on glass-painting is the ancient writer Theophilus; for he creeps in, somehow, whenever this subject is being discussed. As it will be necessary to mention his book several times in the course of this paper, it will be best to begin by telling what is known about him.

Theophilus was a monkish writer on various arts including oil-painting, metal-work, and glass making and painting. Who he was and even the country in which he lived are alike unknown, the time at which he lived has also been the subject of much debate, but competent authorities say that the earlier copy of the MS. of his book, entitled "Diversarum Artium Schedula," cannot be later than the twelfth century.*

This fact is noteworthy because Theophilus describes processes such as, for example, the method of fluxing jewels on to glass in order to save the unsightly effect of lead and the trouble of leading them in, which are not to be seen in actual work until two hundred years or more later.

There are two methods of making a stained glass window. In the first, known as the "antique," or "mosaic" method, the colours of the various garments, sky, trees, etc., are obtained by cutting them out of glass already coloured in the pot. Each colour, therefore, is on a separate piece of glass and divided from the next by a strip of lead. In the second method, the window is cut entirely from sheets of clear or colourless glass, such as sheet window glass, the colour being obtained by coloured vitrifiable enamels similar to those which are used for painting on china. These enamels were not introduced in windows until the sixteenth century, so that, as I intend to confine my remarks solely to mediæval glass, the subject of coloured enamels must be dismissed with this passing reference.

The first stage in the making of a stained glass window is to draw the cartoon. According to Theophilus, this was drawn on one end of a whitened board supported on trestles like a table. The other end of the board, which was blank, served to lay out the pieces of glass upon, paint, and afterwards glaze them.

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* The entire treatise was published with an introduction by Leiste in 1781 in the "Beyträge zur Geschichte und Litteratur aus den Schätzen der herzoglichen Bibliothek zu Wolfenbüttel," Braunschweig. The second book, which treats of glass-making and glass-painting, was printed in English by Winston in his "Hints on Glass-Painting," 1847. Appendix A.

Sources of Glass in Mediæval Times.

The essence of a painted window is not the paint but the glass. Although vigorous schools of design in glass flourished throughout the whole of the mediæval period and for long after at London and at York, and there windows by the hundred or even the thousand were designed and made, all the glass, or practically all, had to be imported from the Continent. Although, in 1449, Henry VI brought John Utynam, a glass manufacturer, from Flanders in order to make glass of all colours for the windows of King's College, Cambridge, and Eton College, and gave him the first patent of monopoly ever granted in England, the experiment was probably a failure and we hear nothing of the manufacture of coloured glass in England before or since.

There were two glass-making areas on the Continent, the northern and the southern, German and French, answering to the two centres for glass-painting, northern and southern, in England. The northern glass-making area was situated in the forests on the banks of the upper reaches of the Rhine and its tributary the Moselle. Glass was made there because the chief requirement of the glass-maker was an abundant supply of fuel close at hand and water to enable him to transport his glass, when made, to its destination. The glass was floated down the rivers to ports such as Bruges or Antwerp at the mouth, whence it was transhipped to England by the Hanse or the Merchant Adventurers. This glass was known as Hass, Burgundy, or Rhenish.

The southern area comprised the glass-making districts of the Seine and its tributary, the Marne, the glass made there being brought to ports such as Rouen, whence it was exported to England. This glass was known as Lorraine and Normandy glass.

The northern and southern glass-painting schools in England naturally each drew their glass from the nearest source, the ports of entry being Hull and London respectively. There is, therefore, as we might expect, considerable difference between the glass to be seen in windows in various parts of the country. Some colours used in the south are never seen in the north, whilst those which are common to both vary in tint to a very great extent.

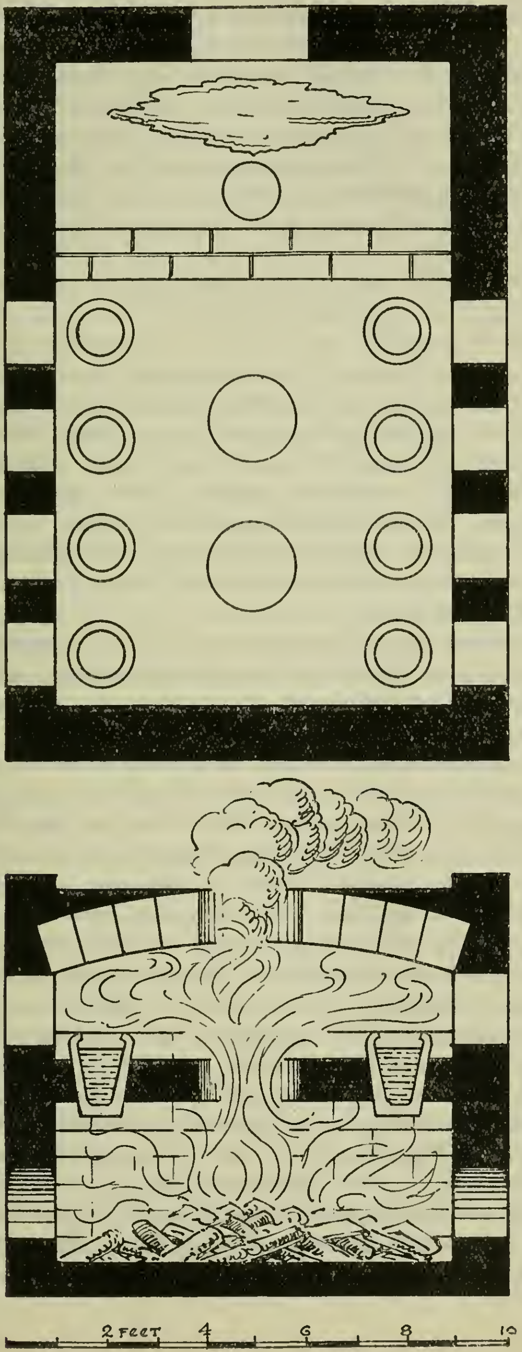
The chief differences between the glass used in windows at the present day and that employed in mediæval times is that the ancient glass was a potassium–calcium–silicate, whereas the alkali used nowadays is generally soda. Also, although mediæval sheet glass was produced by both the crown and the muff processes, the former has been practically abandoned and all the glass used in modern windows is muff, that is, a cylinder of glass having been formed, it is cut down the side and opened out into a flat sheet, as opposed to crown, which is formed into a round sheet by whirling.

Although Theophilus describes the muff process only for making a flat sheet of glass, we know that crown was equally common. The centre pieces of the tracery of the fifteenth-century windows in the north clerestory of St. Martin-le-Grand, York, were formed out of the centres of crown bullions, and one frequently comes across pieces of glass corroded in arcs of concentric circles, showing that they are parts of crown sheets. In St. Saviour's Church, York, the head and body of our Lord in the tracery of the east window have been cut up against the edge of a crown sheet, so that the original selfedge edge remains. By making the usual calculations, after measuring the arc, it appears that the original sheet was twenty-four inches in diameter. M. Appert gives the diameter of similar sheets found in French windows as 60 to 70 cm. Whether a sheet of glass has been made by the crown or by the muff process can generally be detected, even if the selfedge edge has been cut off, from the direction of the bubbles. If these run in straight lines parallel with one another, the glass is muff; if, however, they run in ever-widening circles round a centre, like ripples on the surface of water after a stone has been dropped in, the glass is crown.

It is not possible to devote space to discuss the interesting question of the various types of mediæval furnaces, but I should like to direct attention to Fig. 1, which I have drawn from the description of the furnace contained in Theophilus's treatise, as it has not been shown before. This furnace, it will be noticed, differs in several respects from the usual type. In the first place, instead of being round, as most of the mediæval furnaces were, it is rectangular, being 15 feet long by 10 feet broad. It was divided into two stories by a floor. The flames from the fire below ascended through three round holes, and the pots, instead of being placed on a siege, fitted into more holes and projected through beneath. In plan, the furnace was divided into two portions by a wall which reached only an inch or two above the floor. In the larger of the two the batch was melted, whilst in the smaller it was subjected to a preliminary roasting or fritting.

As previously remarked, there is a considerable difference between the glass of the north and south of England. This is particularly true of the uncoloured or "white" glass. In the north, it is very much "whiter" than in the south. At York, practically all the colourless, as well as the coloured, glass was imported, but in the south it is possible a great deal of the colourless was native. In 1351 the glass-works at Chiddingfold supplied no less than 1600 lb.

FIG. 1.



of glass in one order and 1500 lb. in another for the windows of St. Stephen's Chapel, Westminster, and St. George's Chapel, Windsor. It should be remembered that these windows were a "rush job," and Edward III, in order to get them done as quickly as possible, not only seized all the glass available for the use of the King, but impressed glass-painters from many parts of England and brought them to Westminster to paint it. It was also but two years after the terrible scourge known as the Black Death, which must have greatly interfered with the supply of glass from overseas.

The Colour of Old Glass.

Old glass is generally said to have a horny quality, but it is doubtful whether this is due to anything more than physical causes and the patina on the surface of the glass. When a piece of old glass is chipped on the edge so as to show the clear metal, or the surface paint and dirt or other accretions are removed with hydrofluoric acid, it does not appear in any way different from modern glass. It is extraordinary how "white" a great deal of the York glass is. When a piece is cleaned and laid on a piece of white paper it shows but a mere trace of tint, and inclines rather to yellow than to green.

The green tint in glass, such as is to be seen in modern common bottle metal, is due to a trace of iron oxide which gets into the batch as an impurity of the sand. To remove or to counteract it, manganese dioxide is generally employed. Although the use of manganese is indicated by Pliny, Theophilus does not mention its use in glass-making, but it is certain that it was employed for producing purple, as analysis proves. Moreover, Eraclius, a writer of the thirteenth century, speaking of purple glass, says that after prolonged heating it will "turn to paleness. From this pale colour it turns to another, which is called membrum" (that is, flesh-colour). This description exactly describes the behaviour of manganese when introduced into the glass-batch in the form of a natural pyrolusite ore, as no doubt it would be in ancient times. Moreover, according to M. Chesneau, the "membrum" or flesh-tint colour cannot be obtained with pure MnO_2. Manganese only imparts a purple tint to glass when in the state of highest oxidation. After prolonged heating in a reducing atmosphere, such as the mediæval furnace provided, the MnO_2 is gradually reduced to a lower oxide which imparts no colour to glass.

The mediæval glass-makers were ignorant of the cause of this phenomenon, and had therefore to work off as much of the metal as they could whilst it still retained its colour and put this aside to be used for the heads and other flesh tints in the figures in windows. This probably accounts for the fact that whilst all the early figures have the heads cut out of flesh-tints, at the beginning of the fourteenth century when the use of stained glass became more extended, some of the heads are pink and some white, probably due to a shortage of tinted glass which, seeing that the production of it was accidental and beyond the power of the glass-maker to produce at will, necessitated colourless glass being used instead, or, in order to eke out the supply of tinted as we see in the windows of the Chapter House at York, and this led eventually to the use of pink, or rather salmon-tinted glass, being entirely abandoned and colourless glass used exclusively in its stead.

It is generally said by vergers and others who conduct visitors round our cathedrals and churches that it is impossible nowadays to make colours such as are to be seen in ancient windows. So far from the present-day glass-maker being unable to rival his mediæval predecessors, the reverse is the case. Modern practical skill assisted by scientific research enables colours to be produced with a certainty and in a far greater range of tints than was ever possible in former ages. With the notable exception of ruby, for the production of which we must give the highest praise to the mediæval glass-makers, all the other colours are those which are the most easily produced. Being made mostly from natural ores which contained, as impurities, other metallic oxides each of which was capable to a greater or less degree of imparting its own particular tint to the metal, the resultant tints were not primaries, but secondaries containing traces of other tints and colours. They, therefore, always harmonise with each other, but the mediæval glass-maker must not be given credit for this, successful as the ultimate result was, and certainly not the glass-painter, as he had no choice but to take what was offered. It was entirely due to circumstances over which they had no control. But since a colour which is easily produced is obviously cheaper to produce on a commercial scale than one which requires delicate and difficult manipulation; and since crude oxides are less expensive than chemically pure ones, exact facsimiles of many of the mediæval colours with exactly the same imperfections in the blowing and founding of the metal and the same variations of tint are to be met with every day in the commonest modern bottle-ware. If a number of whisky, gin, aperient water, stout, and similar bottles be collected, the ends cut off, and the small cylinders so formed slit down the side and opened out, we at once have a selection of small sheets of yellow, brown, green, and tinted glasses with the same texture and the same soft range of tints as are to be seen in old windows.

To take now the several colours in order and discuss each one more particularly, we will start with the blue. Although Beckmann in his "History of Inventions" wrote an elaborate article to prove that cobalt was not known before the first quarter of the sixteenth century, analysis proves, and comparison of tint with blue glasses of known composition shows, that all the mediæval blues are what are known as red-blues and were produced from cobalt; in fact the famous Barberini (Portland) vase was produced with cobalt oxide. The blues in ancient windows are very variable even at the same period, and range from grey to the most intense, although never crude, blue. This points to the employment of an oxide of varying purity. The York blue is very characteristic. In the fifteenth century, although, as at other times, there was very considerable variation, it can generally be described as inclining to slate-colour. The biting blues of crude tint so much in evidence in the Scrope and other windows in the Minster were inserted during the recent restoration. About the beginning of the sixteenth century the tint of the blue suddenly changed and it appeared as a deep rich royal blue, to produce which an oxide in a purer state would no doubt be required. These intense, but at the same time harmonious blues, for they have been used side by side with ruby, are to be seen in the windows of St. Michael-le-Belfry Church, York, which were inserted about the year 1528; and we know that the coloured glass used in these windows came from Burgundy.

One of the chief impurities of cobalt oxide in its natural state is nickel. In this connection M. Chesneau contributed some interesting observations in a communication to the Academie des Sciences in 1915 * upon a series of analyses he made of coloured glasses from the west rose window of Rheims Cathedral. He remarks that whilst traces of the oxide of nickel were found in the purple and the green glasses, there was none in the blue, and he believes that as early as the thirteenth century the presence of nickel was known and steps were taken for its removal.

This is a point which needs further investigation, and can only be done by a thorough and systematic series of analyses of ancient glasses of established date and known provenance. It is very much to be regretted that ecclesiastical authorities have hitherto entirely failed to see the importance of this, or to offer facilities for its being done when works of restoration are being undertaken. It is not merely a question of establishing what colouring oxides are present in ancient glasses; but the information obtained would

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* *Compt. rend.*, 1915, **160**, 623.

add enormously to the little which is at present known of the extent of the knowledge of chemistry in the middle ages.

A test, but by no means a conclusive one, which lends some colour to M. Chesneau's contention is provided by the fact that if a piece be cut from the thinner part of the side of an ordinary modern poison bottle, pieces of ancient glass can be found which will exactly match it, and if the modern piece be similarly painted and daubed to imitate dirt it is impossible when the two are placed side by side to tell which is which, and we know that the modern blue poison bottle is produced from pure cobalt oxide.

The green glass, like the blue, was very variable in tint. It was very little used after the fourteenth century except for trees and frequently even those were cut out of "white." Analysis shows that it was made, as in the case of bottle-ware at the present day, from iron and copper.

Purple of a deep tint was also practically abandoned after the beginning of the fifteenth century. At York it is of the characteristic pickle-cabbage tint obtained with manganese. In the ante-chapel of New College, Oxford, the robe of one of the figures is cut out of a most beautiful blue-purple which cannot be matched at York. M. Chesneau in the series of analyses of the glass from Rheims directs attention to the high content of potash in the purple and green—more than 18 per cent. as compared with 12·20 and 15 per cent., respectively, in the blue and ruby glasses. He accounts for this by stating that in order to obtain a purple from manganese and green from copper it is necessary to work in a very oxidising atmosphere, and that to attain this and to counteract the reducing action of their furnace gases, the mediæval glass-makers added nitre to the batch.

Formerly all the various coloured glasses used in church windows were called after the precious stone they resembled, but the red glass called ruby is the only one which still bears its fine title. The extraordinary thing about this colour is that in view of the great difficulties, both chemical and manipulative, which have to be overcome in its production, when it first appears it is, from a glass-painter's point of view, more perfect than at any subsequent period. In fact, from the artistic point of view its history is little more than the tale of its decline.

All the mediæval rubies were copper rubies, and made from the cuprous and iron oxides. One of the chief difficulties consists in the fact that the cuprous oxide, to which the red colour is due, is very liable to pass over to the cupric condition, when it imparts a green colour to glass. In the manufacture of ruby not only must all oxidising substances be kept out, but strong reducing agents must be employed. To some extent the mediæval glass-makers had things in their favour, for the ancient furnace was a smoky affair and conditions were therefore favourable for keeping the copper in the lowest state of oxidation.

Mediæval ruby was always flashed, as also is the invariable practice in the case of rubies used in stained glass windows at the present day; for the production of a pot-metal ruby, whilst not impossible, is so rarely done as to amount practically to a curiosity. I have been shown a window which was designed and the glass itself made by Mr. Clement Heaton, formerly of Neuchâtel, in which the rubies were pot-metal. Pot-metal rubies, made under a patent of Goerish and Co. of Dresden by Herr Putzler of Penzig, Silesia, are also to be obtained for photographic purposes.

Seeing that all the glass had to be imported, it is not surprising to find that at times, as the result of wars and the operations of sea-pirates, the supply was frequently cut off. This is particularly true in the case of the ruby. There is next to no ruby glass used in York windows round about the year 1470. The east window of Holy Trinity, Goodramgate, and the window painted to a great extent from the same cartoons in the south aisle of St. Martin-le-Grand, Coney Street, contains very little ruby glass, a manganese pink of a rather unpleasant tint being largely used instead. The windows in the north clerestory of the latter church, which are about the same date, have likewise the smallest possible quantity, and some of them none at all except small pieces in the border which would probably be cut from waste left over from previous windows. As ruby glass has been used in windows both before and after this date without stint, the economy practised in windows of this period can only be accounted for from the fact that the supply had been temporarily cut off. This is probably explained by the Hanse war begun in 1468, which interfered greatly with overseas trade.

A good illustration of the effects of this war on commerce is provided by the history of Memling's "Last Judgement," now at Danzig, which was prevented from being taken to Italy for several years, and when finally shipped was captured by a privateer and the cargo, including the picture, taken and sold.

An entry in York Minster Fabric Rolls for the year 1471 provides what is probably another sidelight upon the difficulties of overseas trade and the impossibility of obtaining foreign glass, for in that year we find that one seam (that is, 24 stones) of English glass was bought for the windows of the Great Lantern Tower.

During the first quarter of the seventeenth century the art of making ruby glass gradually died out, and eventually entirely disappeared, the end being probably hastened by the wars which devastated Lorraine in 1633. Glass-painters were forced to imitate flashed ruby as best they could, and this they did by choosing a colourless glass which was capable of receiving a good stain, and repeatedly staining it with silver, thereby obtaining first a yellow, then an orange, and lastly a red. The glass used for this purpose was known as Kelp, made with the alkali which bore that name obtained by burning sea-weed.

The true ruby was again revived shortly afterwards; for we find the Price Brothers early in the eighteenth century advertising that "the said *Red* and all other colours" were again made "to as great a degree of Curiosity and Fineness as in former Ages by William and Joshua Price Glasiers and Glass-Painters near Hatton Garden in Holborn, London."

Still again, however, the art was lost, although it was probably known to a few persons. To M. Bontemps belongs the honour of having in 1826 revived the manufacture of ruby in France, and to M. Engelhardt in 1828 in Germany.

It would seem, however, that what was lost was not so much the art of making the red as the method of flashing it upon colourless glass. For this William Peckitt of York, the glass-painter, took out a patent in 1780, and in St. Michael's Church, Spurriergate, York, there is a piece of flashed ruby glass bearing the name of another York glass-painter, John Barnett, and the date, 1821, at which time the method of manufacture had everywhere else been entirely lost.

The question of flashed glasses is very interesting. Some writers have stated that all the earlier rubies were pot-metal, which is extremely doubtful. On the other hand, M. Appert, in his "Note sur les Verres des Vitraux Anciens," states that he has met with examples formed of seven distinct layers of different colours. Apart from the fact that a sheet of glass formed of seven colours one behind another would be perfectly opaque, it is difficult to see what practical advantage would be gained or when such a glass would be found useful except in very rare instances in heraldry. As the only advantage of such a glass would be that all the different colours could be shown at once in the same piece of glass and so avoid the use of leads, the glasses above and below the required colour would have to be ground away, leaving the one desired, which, consisting of nothing but the flash without any colourless glass supporting it as in ruby, would be as thin as paper. Thus, when all the unwanted colours had been ground off from the front and back the resultant piece would be of a very delicate structure indeed and very extraordinary in section.

If, however, we may be allowed to term white and black colours, seven different colours can be easily obtained in one piece of glass with two flashings only, and by the use of yellow stain; but that is an entirely different matter. If a colourless glass be flashed red on one side and blue on the other, by removing the red flash we get blue and *vice versa*. The two in conjunction give purple, blue on one side and yellow stain on the other give green, and both flashes removed by acid and the white stained give yellow, whilst the ordinary glass-painted enamel gives black. Thus, white, yellow, red, purple, blue, green, and black, give seven colours in a perfectly legitimate way.

Gold pink or gold ruby is commonly stated in all the books not to have been discovered before the sixteenth century. It is possible, however, that it was known although rarely used long before this. A MS. of the fifteenth century preserved in the convent of S. Salvatore at Bologna gives recipes for dissolving gold in aqua regia and precipitating it by means of a solution of tin, and for obtaining a rose-coloured glass-mosaic for the precipitate. A MS. in the British Museum which was transcribed in 1572, " out of an old copye, which copye seemeth to be above 200 years old," gives several recipes for glass in which gold was employed as the colouring agent, and the Rev. Canon Fowler states that the pink glass in the St. Cuthbert window at York (*c.* 1436) owes its tint to the same precious metal. It is quite likely in view of the fact that, although the window contains 85 panels, this pink has only been used in the figures of the Lancastrian Kings, Henry IV, V, and VI.

It should not be forgotten, however, that a pink fairly close to that derived from gold can be obtained by manganese. All these interesting points will only be finally cleared up when ecclesiastical authorities have been brought to realise the importance of expert scientific and technical advice on all works of restoration, instead of, as is too often the case at the present day, leaving the work entirely in the hands of mechanics.

The Production of a Stained Glass Window.

We will now consider for a few moments the technical details of glass-painting. The first stage consists in the production of a drawing known as the cartoon the full size of the window or of a portion of it. According to Theophilus, this was done on one end of a whitened board, whilst on the other, where there was no drawing, the glass was laid out, painted and afterwards glazed. The various pieces of glass, having been cut to shape out of sheets of the required colour, were laid on the drawing and the details such as eyes, nose, mouth, folds of drapery, inscription, and so forth, painted in outline with vitrifiable pigment and afterwards shaded with thin washes of the same pigment.

The vitrifiable enamel, or "colour," as glass-painters call it, is solely intended to block out the light in varying proportions and so obtain shading. Opacity is, therefore, one of the chief requirements. The enamel must also vitrify at a lower temperature than would be required to melt the glass to which it is applied. The enamel consists of two parts, a metallic oxide such as the oxide of copper or of iron, and a soft glass ground to a fine powder which is mixed with the oxide and is known as "flux." At a temperature varying from dull to bright red the flux "melts" and attaches the opaque pigment to the surface of the glass just as the size in whitewash holds the lime or whiting to the ceiling.

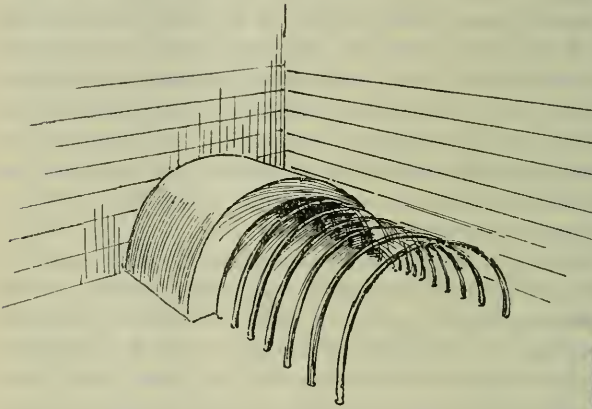
I will not stop to consider the composition of glass-painters' enamels at different periods now, as I fully discussed the whole subject some years ago in a paper read before the Society of Arts. I will merely say that I was able to show that "Greek Sapphire," which Theophilus instructed should be used to paint glass with, was azurite or blue carbonate of copper, as this substance is the only one which fulfils all the conditions, and moreover agrees with the descriptions we have of how it was used and its behaviour when employed.

The glass having been painted had next to be fired. This was done, according to Theophilus, in a kiln constructed as follows: A series of twigs was bent into an arch shape (Fig. 2) and the ends stuck in the ground. Upon this foundation, clay mixed with horse-dung and chopped hay, was placed to the thickness of three or four inches so as to form a little tunnel, as it were, and in this the glass was fired on an iron tray raised sufficiently off the ground to allow of a fire being kindled beneath.

In laying the glass on the tray (Fig. 3) Theophilus instructed that the green and blue glass should be placed nearest the handle, that is, nearest the opening or mouth of the kiln (Fig. 4), and the other colours and the white glass further in as they would stand the heat better than the former.

We have here a good illustration of how, by reading between the lines, much valuable information of the state of ancient scientific knowledge may be obtained from the often strange medley of useless and frequently fantastic ingredients in mediæval recipes and books of secrets. Many of these, at first sight, seemingly ludicrous ingredients are capable of scientific explanation; for example, the object of mixing chopped hay and horse-dung with the clay for the roof of the kiln was to make it porous and so prevent cracking, and it is possible the Israelites were unable to make bricks without straw for the same reason. Nowadays, in the repair of kilns it is usual to use a mixture of fireclay, sawdust, and waterglass (silicate of soda). By the heat of the furnace the sawdust is carbonised and so the fireclay becomes full of cavities like a sponge and less liable to crack.

FIG. 2.



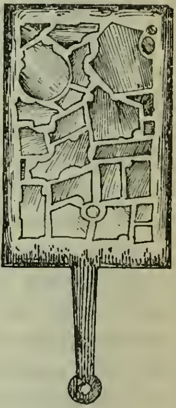


FIG. 3.

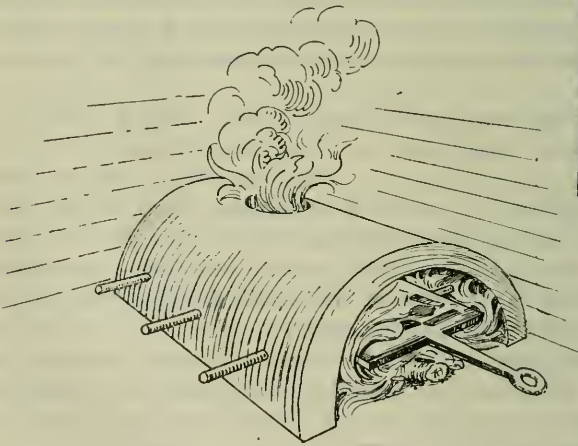


FIG. 4.

There was also sound reason for placing the blue and green glasses on the tray near the mouth of the furnace, where on account of " cold mouth " from which all kilns suffer, they would receive less heat than the parts further in the interior of the kiln.

I have shown that the blue glasses were derived from cobalt and the green from iron, but there were evidently other blues and greens which owed their colour to copper. We know that at the present day "signal green," which is actually a blue derived from copper, is of a highly fusible nature, as all glasses containing copper are, so much so in fact that they can scarcely be fired even at the low temperature which a glass-painter's kiln attains without being melted. In the manufacture of glass "colour" or the vitrifiable pigment with which the glass was painted, Theophilus instructed that green glass should be pounded up and used as a flux to attach the metallic oxide to the surface of the glass. This shows of what a highly fusible nature this green glass was, and it was so highly fusible because it was a copper and not an iron colour.

The Decay of Old Glass.

York glass, especially that of the fourteenth century, was particularly liable to decay. Although the Dean in his appeal on behalf of the windows states, "No one knows the cause of it," whilst another dignitary of the Church tells us "birds peck the glass, and in a few centuries make a perceptible mark in the surface," * these statements merely show that modern scientific knowledge is not yet as widely applied as it might be. The fact that glass is liable to decay has been remarked for centuries. The Romans noticed it. In later times it was supposed to be due to the moonbeams, so that it was frequently the custom to insert a clause in contracts for windows for churches, as, for example, in the case of the windows of the Cathedral of Auch, in 1647, that the glass used to paint on should not be "crinkled nor spotted nor liable to injury from the moon." Palissy, the potter who in early life had been a glass-painter, was thoroughly acquainted with the way the glass in windows corroded, and whilst ridiculing the moon theory pointed out that it was due to "the damp and rain which have melted part of the salt of the glass"; which explanation, whilst it does not cover the whole ground, is very close to the actual truth, whilst Hardiquer de Blancourt, in the Preface to his "Art of Glass," 1699, noted how Venice glass "will Dissolve in the Earth or in cold and moist Places if there be more Salt in it proportionately than Sand, by a Separation natural to those two sorts of Matter."

The phenomenon of the devitrification of glass caused by decay has, therefore, been long known. It is in no way due to age, for often the earlier glass is the best preserved. I have seen modern bottles troubled with the same defect. In one case, common machine-made medicine bottles destined for Bangkok, were packed in wet straw in crates which had stood outside in the firm's yard for some time. On arrival in the Straits Settlements, the whole consignment was found to be in an advanced stage of decay.

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* Lecture delivered at Sleights by the Rev. Chancellor Austin, reported in the *Yorkshire Herald*, July 8th, 1922.

Pits in varying stages of formation are also frequently to be seen on the inner side of pressed glass-ware such as shrimp-paste and similar products are packed in. The subject of corrosion has received considerable attention and been the subject of several papers read before or communicated to your Society. There will therefore be no need to discuss it further. Many points, however, still require elucidating, such as, for example, why pitting rarely occurs where the silver stain has been applied to the surface of the glass, and why corrosion on one side of the glass frequently follows the lines of painting on the other. These and similar questions I leave to your consideration at some future time.

23 Stonegate,
York.

Discussion.

Prof. W. E. S. Turner, in opening the discussion, said that Mr. Knowles's address had been full of interest, and seeing that the Society had been engaged for the past few years in more or less utilitarian and directly technical pursuits, the lecturer's subject had come to them as something of a novelty. But Mr. Knowles had gone farther than bringing a novel subject; he had actually introduced topics in which the glass manufacturer, in whatever branch of the trade he might be operating, was capable of taking a deep interest and of discussing. Such questions as the development of coloured glass and the decay of glass were of great interest to the Society.

The address had touched on several points of moment. In the first place it was a matter of very great interest that some of the colours which were being produced at the present time in the commonest sort of fashion and in the easiest possible manner in connection with the bottle trade, were very much the colours which the mediæval glass-maker used. There had been a tendency for a long time to give the mediæval glass-maker a halo of undue credit for many of his productions, whereas the truth was that the glass-makers of the present age could, and did, make far better glass than was ever made before. He was particularly interested in Mr. Knowles's reference to cobalt oxide, and to the statement which Beckmann had made that this was not used before the twelfth century. He (Prof. Turner) thought that it was perfectly and definitely proved that samples of Roman glasses were coloured both by copper and by cobalt, so that cobalt was known and was used in the process of Roman glass-making. He believed also that Sir Humphry Davy's analyses of samples of Egyptian glass had brought to light, not only copper, but also cobalt in those glasses. It was obvious, therefore, that the use of cobalt went back many centuries.

Whilst speaking of colours, the mention by the lecturer of the production of a yellow stain by means of silver salts reminded him that the red obtained with copper—copper ruby—could also be produced in a similar way. This was something which Mr. Knowles was apparently desirous of knowing. Only that year, in Czechoslovakia, he (Prof. Turner) was shown a process in common use there for producing the equivalent of a ruby flashed glass by means of staining with copper salts. Both with silver and copper staining, the salt was mixed up with clay, and made into a paste, which could be easily and uniformly distributed over the glass. After the firing, the clay could be wiped off as the temperature of firing—which might be anything between 500° and 600°—was not sufficient to make the clay adhere to the glass. In the case of the silver salt, the yellow staining was obtained at once, whereas in the case of the copper colour, the first stage reached was a green tint. The glass was then given a second firing in a reducing flame and came out in the form of a dark, dirty sea-green; and a third firing was given to the glass during which the red colour developed. Thus the copper colour required considerably more time and trouble to produce than the silver colour.

With regard to the question of the decay or corrosion of glass, this should interest the members very deeply. It was one of the objects of their visit to York to see the form and extent of this decay. He and his staff were keenly interested in this subject, as would be evident from the fact that fully a dozen papers had been published by them giving the results of researches on it. Any glass-maker, knew, of course, that the cause of decay was not so much exterior influence as bad glass. It was not a question of age, as some people thought. At Sheffield they had seen samples of glass that had been sent out to the East, which, within a remarkably short time, had exhibited corrosion due to excessive content of alkali, usually soda. They had seen microscope slides, bottles, drinking vessels and table glass generally, all showing this effect.

Mr. F. W. Branson said he would like to ask the lecturer what percentage of selenium there was in the plate of glass shown by him in his demonstration. Mr. Knowles replied that he was sorry he could not give this information. All he knew was that it was a selenium glass. He believed it was a glass of foreign origin. It was a type of glass that was not very much used in glass-painting because it was disposed to go black.

Mr. D. Robertson said he had been most interested in the paper partly because he was at one time engaged in the stained glass and leaded light trade, and partly because he had had the opportunity of visiting quite recently certain cathedrals and churches in France which were now undergoing restoration after the devastations of the Great War. At the cathedral of St. Quentin he picked up a piece of green-tinted glass which came from one of the windows of the nave, situated in an angle of the building. This piece of glass bore distinct evidence of directional pitting, and he wondered if Mr. Knowles had observed this directional pitting on any glass taken from York Minster? Further, he would like to know why it was that the faces and figures in many church windows in England, and for that matter on the Continent too, were drawn out on a nasty dull green body of glass, giving a dead, sickly appearance to the face? Was the flesh-coloured tint already mentioned difficult to obtain or was this appearance preferred? Also, he wondered if Mr. Knowles could say whether or not any traces of Cr_2O_3 had been found in old glasses which had been examined? Was this colouring agent known to the old manufacturers?

Mr. T. Robertson asked whether Mr. Knowles had noticed that paint acted as a protection to the surface of a glass. For instance, a glass might be pitted on both sides, but where the paint was the oxides seemed to act as a protection and pitting was not observed.

Mr. F. E. Lamplough said that the difference between a gold and a copper ruby was very easy to distinguish without the use of a spectroscope. If one combined a piece of ordinary signal green glass with a ruby, then the gold ruby showed a more or less purple colour, whereas in the case of the copper ruby the certain amount of green light which it allowed to pass caused it to show up rather more green in tint.

Mr. Knowles, replying to the various speakers, said that there was ample evidence, as Prof. Turner had stated, that not only were mediæval blue glasses made from cobalt, but the Roman glass of the famous Barberini type, as exemplified by the Portland Vase, was also coloured by cobalt. With regard to the copper stain, it was extraordinarily good news to him to hear Prof. Turner's remarks, and he hoped that glass-painters would be instructed further how to use such stains. He remembered seeing some imitation cut glass in a window which looked as though it had been cut out of a piece of flashed ruby. He had now no doubt whatever that it was produced in the way that Prof. Turner had described. A description as to how to stain a glass with copper was published some years ago by Prof. Barff, who presented a number of analyses on glass, but although his description was a possible one it seemed scarcely practicable of employment by a glass-painter, because of the fact that the glass had to be fired in a kiln containing a reducing gas, such as hydrogen.

With regard to the green stain in windows, particularly for the heads of figures, he thought this was merely a fashion, which, fortunately, was dying out. As to directional pitting, the only instances of this that he had seen invariably started in the form of little round pits, never oval or pointed. Occasionally four or five of these small pits would combine to form a patch, but he had never seen instances of the particular form of pitting such as one of the speakers said he had encountered at St. Quentin.

A question had been asked with regard to chromium oxide. No chromium oxide was used by the ancients for the simple reason that it was quite beyond their technical knowledge to do so. He believed that chromium oxide was first discovered about the eighteenth century. Before that time there were no chromium greens; but it was undoubtedly the ideal of the mediæval glass-makers to make a glass of a chrome tint. All their greens were, however, combinations of oxides of iron and copper.

It was asked whether he had observed that paint protected the surface of a window glass. There were examples of glass at York in which it was clearly shown that the paint applied to the glass had preserved it, for all the rest of the glass had corroded away until the painted parts stood out in relief. In other cases, however, it had been shown that the paint was the cause of decay. It was significant that wherever silver staining had been applied to the glass there was little or no evidence of pitting.

The method described by one speaker of determining whether a ruby glass was a copper ruby or a gold ruby was entirely new to him, and in fact this piece of news was quite a windfall. He wished that he had known it a long time ago, because up to now he had had no method of determining this except by the eye, which could scarcely be relied on as evidence.

Prof. Turner said that he would like to add to Mr. Knowles's statement that amber glasses to-day were being made by the addition of carbon in some form or another. In thanking Mr. Knowles for his paper, he would like to support what Mr. Knowles had said with regard to the value which systematic study and analyses of specimens of ancient glass might afford.

He (Prof. Turner) would like to say that if Mr. Knowles could put into his possession specimens of glasses such as those to which he had referred, he thought something might be done at Sheffield to help him. The opportunities of acquiring specimens of such glasses did not fall to the lot of many of the Society's members, and this was probably one reason why the subject did not attract and bring into the field the activities of the scientific glass-maker and the chemist. If the subject were properly tackled there was little doubt that something in the nature of systematic knowledge might be built up and placed on record.

XXII.—*The Present Position of the Glass Industry in Czecho-Slovakia.**

By Prof. W. E. S. Turner, D.Sc., M.Sc., F.Inst.P.

(*Notes of an Address at the Sheffield Meeting, November*, 1922.)

The Republic of Czecho-Slovakia, created as the result of the war, occupies a very central position in the Continent of Europe. It includes Bohemia and other portions of the old Austrian Empire and contains a population of about 14,000,000 people, of whom the two most important races are the Czechs and the Germans. So far as the glass industry is concerned, we could replace the word "Czecho-Slovakia" by "Bohemia" with advantage, perhaps, to those to whom the newer word is unfamiliar, for the industrial areas where the glass industry is important are just those of Bohemia.

Indeed, the references in pre-war times to the extensiveness of the Austrian glass industry rather misled one to suppose that there were plenty of glass factories scattered through the length and breadth of Austria. So far from this being the truth, it was stated by a German writer some two years ago that when the new Republic of Czecho-Slovakia was set up Austria was left with only 19 glassworks, of which several were engaged in mirror-making, so that the bulk of the articles of glassware in common use would have to be supplied from Czecho-Slovakia.

It was in Bohemia that practically all the Austrian industries were located, this statement applying, not only to glass, but also in a very considerable measure to metal wares and textiles.

The glass industry is very largely concentrated in the fringe of Bohemia adjacent to Saxony, running in the main from Teplitz-Schönau in the north-west to Gablonz in the north-east. In addition, a few factories are located in the neighbourhood of Prague, and also about 30 to 40 miles south-east of Prague, whilst to the west of that city Pilsen is another large centre, more especially for window glass and for bottles.

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* Compare the article by the author in *The European Commercial*, Vienna, September, 1922.

Much of the raw material for glass-making at the present time has to be imported. Thus, the Bohemian factories have relied hitherto for their finest sand almost entirely on the Hohenbocka supplies, and it is only very recently, being driven by absolute economic necessity, that home resources have been examined and to some extent exploited. A number of raw materials such as alkali are obtainable from Aussig, an important manufacturing town in Bohemia, but these factories are, I am given to understand, only branches of chemical factories situated in Germany, so that again German control operates. Practically all the colouring materials, I was told, had to be imported from Germany, and especially those of good quality.

Of fuel, there is a plentiful supply for those districts which are readily accessible from Teplitz-Schönau, since this is a big centre of the brown coal or lignite industry. This material has to be sent long distances to some factories, and I was told that one factory was paying as much as 300 kroner per metric ton for this material, whilst factories in Gablonz appeared to have drawn supplies from Saxony, and in some cases to have paid very much higher prices still.

It had been my hope when visiting Czecho-Slovakia to see quite a number of factories; and, indeed, my reception was so kind everywhere that I think my expectations would have been fulfilled in a very considerable measure. Unfortunately, however, my arrival towards the end of August coincided with a very serious crisis in the Czecho-Slovakian glass industry arising entirely from the instability of the foreign exchanges.

My original intention had been to visit the country at the end of June or the beginning of July. At that time the exchange ran about 240 kroner to the pound sterling, and the value had been stable at about this level for a considerable time. In July, however, and in August, rapid appreciation occurred, so much so that in Gablonz on one of the days of my visit, I obtained only about 128 kroner to the pound, whilst the average value at about the beginning of September was 130.

The first question that occurred to me after some hours in Prague, looking at the various wares displayed in the windows, was how was it possible for the country to carry on an export trade. For, having regard to the existing value of the exchange, the current prices of foodstuffs, clothing, and other goods, were dearer, possibly by 20 to 25 per cent., than in England.

The same evening the answer to this question came in the newspaper reports, that catastrophic happenings were occurring in the glass industry.

According to the *Sozial Demokrat*, general disaster had overtaken the glass industries of the north, ranging from Teplitz-Schönau to Stein-Schönau, and it was stated that on the previous Saturday about 12,000 workpeople had been dismissed, whilst a number of other employees had been put on short time. The report turned out to be substantially true, and the reason was not far to seek, having in view the internal prices and cost of living, and also the absolute necessity of a big export trade if industries were to be maintained.

It needs but a little consideration to show in what a difficult position not only the glass-making industry but also other manufacturing industries in Czecho-Slovakia are placed. In its enthusiasm for independence little thought appears to have been given to the economic needs of the country, and naturally no one could have predicted the extent to which certain foreign exchanges would have become depreciated. So long as Bohemia was a part of the Austrian Empire there was a considerable home market absorbing the produce of the works. Under present conditions, however, I am told on very good authority that in the metal, textile, and glass industries at least 60 to 80 per cent. of the production must be exported if the factories are to be kept in reasonably full operation. As, however, Czecho-Slovakia has, for its immediate neighbours, the countries of Germany, Poland, Hungary, and Austria, with currencies almost worthless, it is obvious that its only good markets must be with England and America, and to a smaller extent with France, Italy, Switzerland and Holland. Some of these countries have erected tariff barriers intending to keep down Czecho-Slovakian importation. England has not done so, and Czecho-Slovakian glass does not pay the 33⅓ per cent. duty which the German goods pay.

The purchase of Czecho-Slovakian glassware could only be profitable, however, with the present internal value of the kroner, so long as the external value was low. This was the case, for example, in 1919, 1920, and 1921. Thus, as late as November, 1921, the exchange was about 370 to 380 kroner per pound sterling, and even at the end of June, 1922, when the value was 240 to the pound, it was still possible to buy Czecho-Slovakian goods profitably. Not so, however, at the present time, when the kroner is 130 to 150 to the pound. Consequently, many of the factories came to a standstill, and such sales as have been effected since September are to a considerable extent from stock. The first sections of the industry to be closed down were those dealing with grinding, polishing, and cutting. The glass-melting sections naturally could not so readily be shut down, but a very large number of furnaces have now been put out of operation.

The manufacturers' first remedy for bringing down the cost of production was a cut in the men's wages, and at the end of August the manufacturers made a demand on the men's unions for 20 per cent. reduction, and expressed their intention of closing the factories unless the men acceded. The men, however, were unable to do so, and it must be admitted that in view of the cost of living a 20 per cent. reduction was a very drastic cut.

It can scarcely be doubted that a somewhat anxious time is in front of the country. The cost of production at the present time is very much greater than before the war, the wages are much higher, whilst there is in operation also a 48-hour week for employees in all large establishments. Moreover, taxation is considerable, and I was told that there was a 30 per cent. tax on coal. Very high tariffs have been in operation for some time, since the policy of the Republic has been to prevent the importation of manufactured articles from abroad, and especially such articles as are capable of being made within the country. In view of the operation of these tariffs, the internal prices of manufactured goods are scarcely likely to fall rapidly, whilst a further difficulty militating against the lowering of prices is to be found in the fact that the two dominant parties in the State, namely, the Agrarians and the Socialists, are concerned in maintaining, the one the price of foodstuffs and the other the level of wages.

There is one admirable trait in the management of the Republic, namely, that the Government has declined to resort to the printing of money. One cannot but admire this attitude and wish the country well out of its troubles, as its inhabitants are a hard-working and a highly intelligent race.

As manufacturers were averse to showing me idle factories, I saw only five at work, these being connected with the manufacture of window glass, watch glasses, chemical and scientific glassware, hollow-ware, and coloured glass rod and tubing, the last particularly for the Gablonz industry. In addition to seeing these works, I met and had discussion with a number of men in the glass industry, and drew definitely the conclusion that as regards plant, equipment, and general methods the industry in Czecho-Slovakia is standing still, relying mainly on its knowledge of a generation or two ago.

In other words, in these particular respects it is falling behind the British factories.

Thus, Siemens regenerative furnaces both for tank and for pot furnaces are still in general use, and I did not see nor did I hear of any recuperative pot furnace of modern type such as have been installed in this country, in Holland, and one or two other countries. Moreover, except for one or two Owens machines for bottle-making, and also for one factory taking up the Fourcault window-glass process, there exists practically no machinery except a certain number of hand presses. Manufacturers appear to have enjoyed a boom period in 1920 and 1921, but did not invest that money as did the firms in this country, despite the E.P.D., in new plant and equipment. One of the contentions of the Czecho-Slovakian glass-workers' Trades Union, when confronted with the demand for reduced wages, was that the manufacturers themselves had not taken advantage of modern technical methods with the view of improving production; and from what I saw there is some truth in the contention.

At the present time, therefore, the Czecho-Slovakian industry enjoys superiority over the British rather in respect of the general higher level of skill of its craftsmen than in the possession of modern furnaces, machinery, and general equipment. It is seriously handicapped, however, by having no sea coast, by having to send its goods long distances by rail through foreign countries, such as Germany, by being surrounded by poor countries so far as purchasing ability is concerned, by high internal prices, and finally by the appreciation of the external exchange so that except for specialities there is little inducement on the part of English and American people to buy.

I cannot help thinking that those manufacturers in this country who invested their money in devices tending to increase production, and reduce prices, will in the long run obtain salvation in view of the situation which I have outlined.

To those manufacturers who still lag behind in adopting up-to-date methods and plant and in engaging scientifically trained men, I would give a word of warning. Much of what I have said about lack of modern plant and machinery in Czecho-Slovakia applies also to Germany; but my information is that the German glass industry has recently taken steps to re-equip itself with the most approved American machinery and plant. In these days of international competition, success in trade comes to depend more and more on efficiency and enterprise.

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Appendix.

Since the above address was delivered an interesting article on the "Economic Situation of Czecho-Slovakia" by Dr. Hans Wismeyer in *The European Commercial* of November 18th, 1922, shows that the general position remains unchanged and provides confirmation of my observations made in the above article.

XXIII.—*Some Aspects of the Autoclave Test for Testing the Durability of Glass.*

By William Learmonth Baillie, F.I.C.

(*Read at the London Meeting, December* 13*th*, 1922.)

The most authoritative information on the durability of materials is to be gained only from accurate observation of their resistance to corrosion and wear under normal conditions of practical use. The time factor involved generally precludes this as a method of testing and in the case of glassware renders accelerated tests imperative. Durability can only rarely be defined in terms of resistance to specific substances and ordinarily signifies vaguely an average degree of resistance to attack by a variety of reagents, mainly in aqueous solution. Nevertheless, if durability tests are to be reasonably expeditious, a single reagent must be employed and in practice water, as the commonest corrodent, is usually selected. It is well known that this course is by no means free from objection,* but it appears to be the only alternative to conducting a prolonged series of tests, using a considerable variety of reagents, on every sample received.

Other difficulties are also encountered in devising durability tests for glassware. Durability depends, not only on the composition of the glass and the nature of the corroding agent employed, but also on the method of manufacture and, to some extent, on the purpose for which the article is designed. The problem is still further complicated by the facts that our knowledge of the chemical constitution of glasses is far from complete and the chemistry of their corrosion is still less advanced, so that the method and extent of the acceleration adopted must be fixed empirically, and we cannot be certain that, in accelerating corrosion, we are not introducing disturbing factors.

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* Walker, *J. Amer. Chem. Soc.*, 1905, **27**, 865; Cauwood, English, and Turner, this Journal, TRANS., 1917, **1**, 153; Jackson, *Brit. Sci. Inst. Res. Assoc. Rept.* on "Durability of Optical Glasses," October 1921, pp. 6–12; Turner, this Journal, TRANS., 1922, **6**, 42.

Tests with water or water vapour and conducted below, at or above 100°, have been devised in considerable number. Typical procedures have recently been described and discussed by W. E. S. Turner.* Many of these tests present practical advantages and none is free from objection in some direction, but for general purposes autoclave tests are believed by the author to be the most satisfactory. Autoclave tests in which steam is the corrodent have been found to be flexible (that is, the appropriate conditions can be selected to give rapidly a suitable degree of severity to suit the type of glass), time and pressure may be accurately controlled, the apparatus is compact, robust, and readily available, and does not involve elaborate or expensive accessories, while the results are reproducible and have been found by experience to afford trustworthy indications of quality. Steam tests have also the important advantage of eliminating the complications introduced by diffusion phenomena when water is employed and so are applicable to test pieces of any shape or internal capacity. For this reason, it has not hitherto been considered necessary to employ tests with superheated water in this Directorate, although it is hoped to investigate the correlation between such tests and steam tests at identical pressures.

Selection of Conditions of Test.

It is important to note that there are, in general, optimum conditions of test for each type of glass, and that any considerable deviation will impair the critical quality of the results. Thus, water vapour at 80° will discriminate effectively between optical glasses,† but such a test, conducted for thirty hours, barely affects the hardest apparatus glasses.‡ Treatment with steam at 90 lb. per square inch for three hours has been found adequate in testing chemical ware of "resistance" quality, but such conditions are much too severe for commoner glasses. The following times and pressures have been found satisfactory for the types of glass specified, adopting otherwise the procedure already described. §

Resistance quality apparatus glass	3 hours	90 lb. per sq. in.
Superior blown ware	3 ,,	50 ,, ,,
Softer blown ware	2 ,,	30 ,, ,,
Bottles for ordinary laboratory purposes ...		

The application of the autoclave test to the determination of the durability of optical glasses is now being investigated, but conditions of test cannot yet be recommended.

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* Turner, *loc. cit.*, p. 30.

† Elsden, Roberts, and Jones, this Journal, TRANS., 1919, **3**, 52.

‡ Baillie and Wilson, *J. Soc. Chem. Ind.*, 1922, **41**, 50T.

§ *Ibid.*, pp. 45–55T.

The Choice of Test Pieces.

Since polished surfaces differ in reactivity from fractured faces,[*] it is desirable to determine the durability of glasses by testing finished articles whenever possible, and, in other cases, by cutting suitable pieces and testing them after allowing the edges to "weather" naturally for a few days in a dust-free space.[†]

The employment of powdered glass, suggested by Mylius and others,[‡] has recently again been advocated.[§] The advantages of increased area and the promise of the diminution of the disturbing effects of inhomogeneities [||] are obvious and important. There is reason, however, in the author's view, to believe that the disadvantages of this procedure are altogether too grave to justify its adoption. Sieving is necessary, but cannot profitably be carried to greater refinement than is represented by a difference of 10 meshes per linear inch in the gauze of the sieve. Even if the difficulties attendant on the presence of very fine adherent powder can be overcome by washing the grains with an inert liquid, the actual surface exposed cannot be estimated with any accuracy. Turner has alluded to the practical difficulties introduced by the presence of needle-shaped particles.[¶] Preliminary observations made here in another connection indicate that when glasses are crushed to 80–90 mesh size uniformity in grain shape is not attained, granular, flaky, and acicular types occurring together. In addition, the proportion of each type present appears to depend, in some measure, on the type of glass in question. There cannot, therefore, be any simple relation between sieve grading and grain volume, and so any calculation of surface exposed is rendered very uncertain. Further, there appears to be reason to doubt the reproducibility of the relative proportions of the various types of grains in successive grindings. In this connection it may not be without significance that Nicolardot [**] obtained somewhat different results on blown ware and powdered glass of identical composition in certain tests. Even in the most favourable circumstances, Turner [*] found coarse grains (20–30 mesh) to give only "reasonably concordant results," and under ordinary laboratory conditions, especially in commercial laboratories, it is doubtful whether this degree of success could be achieved. Elutriation might lead to greater uniformity in grain surface, but the possible advantages of this process would be more than offset by its tedious nature and the close control required. With fine powders, such as were employed by Kohlrausch,[†] and more recently by Peddle,[‡] the chances of variation appear so great that the results can be little more than vague indications of durability. In addition to the possibility of cementation of the grains when decomposition of the glass powder becomes extensive, which would prevent complete removal of liberated alkali by washing after the test, there is a danger, which also becomes more pronounced as the fineness of grinding is increased, of the powder "packing" during the test and so preventing free and uniform circulation of the corrodent. On all grounds, therefore, the employment of ground glass in durability tests cannot, in the author's view, be regarded as desirable.

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[*] Jackson, *loc. cit.*, p. 6; Rees, this Journal, TRANS., 1922, **6**, 43.

[†] Baillie and Wilson, *loc. cit.*, p. 47T.

[‡] Mylius, *Zeitsch. Instrumentenkunde*, 1888, **8**, 267; Mylius and Förster, *Ber.*, 1889, **22**, 1092, and *Zeitsch. Instrumentenkunde*, 1889, **9**, 117; Kohlrausch, *Ber.*, 1891, **24**, 2560.

[§] Hagmaier, *Met. Chem. Eng.*, 1917, **16**, 604; Peddle, this Journal, TRANS., 1920, **4**, 36; Turner, *loc. cit.*, 39; Travers and Bunce, in discussion of the foregoing paper, *loc. cit.*, 43, 44.

[||] Turner, *loc. cit.*, 40.

[¶] *Loc. cit.*, 41.

[**] *Compt. rend.*, 1919, **169**, 335.

Criteria of Durability.

The durability of a glass may be estimated from the alkalinity liberated during test, the degree of surface attack (clouding or actual disintegration), the residue on evaporation, and, in certain cases, the change in weight of the specimen.

According to the author's procedure, alkalinity is usually determined by titration with $N/500$-acid, using as indicator an ethereal solution of iodoeosin, but it is occasionally necessary to employ $N/50$- or even $N/20$-acid, when methyl-red may be used. The determination of total alkalinity in this manner, as distinct from the free alkalinity, appears to be the only trustworthy procedure. It is recognised that this criterion is in some measure empirical. It is undoubtedly true, in a general sense, that the alkalinity liberated at the surface of a glass is a function of its content of alkali metals, as is shown by the following data, but the total alkalinity, determined by titration, is not necessarily due to alkalis alone, and the amount of actual alkali liberated depends on the remaining constituents of the glass.[§] It therefore follows that, to be most informative, the results of titration should be considered in conjunction with the analytical data; but it is nevertheless true that the alkalinity liberated is of considerable value as a criterion of durability.

[*] *Loc. cit.*, 41.

[†] *Ann. d. Phys. u. Chem.*, 1891, **44**, 577.

[‡] *Loc. cit.*

[§] Cf. Baillie, this Journal, Trans., 1922, **6**, 68.

TABLE I.

*Alkali-content of Glass and Durability.**

Reference letter.	Alkali oxides, per cent. K$_2$O.	Na$_2$O.	Total.	Order by Alkali-content.	Durability tests.
A	tr.	7·38	7·38	1	5
E	1·09	10·02	11·11	2	2
F	1·59	9·90	11·49	3	4
C	0·34	11·81	12·15	4	3
G	5·92	6·46	12·38	5	7
D	2·58	11·52	14·10	6	1
I	1·47	15·08	16·55	7	8
J	3·50	13·06	16·56	8	9
B	4·02	13·42	17·44	9	6
H	0·73	17·62	18·35	10	10

TABLE II.

Alkali-content and Durability.†

Reference No.	Alkali oxides, per cent. K$_2$O.	Na$_2$O.	Total.	Order by Alkali-content.	Durability tests
205	3·11	6·33	9·44	1	1
224	0·64	13·98	14·62	2	2
204	3·90	12·17	16·07	3	3
207	6·14	12·40	18·54	4	5
225	4·40	14·47	18·87	5	4
206	8·36	12·34	20·70	6	6

The concordance between the last two columns of the above tables substantiates the existence of a broad relation between alkali content and durability, but the latter is evidently considerably affected by other factors in addition.

Superficial deterioration is judged visually after drying the specimen for one hour at 100°, the soluble corrosion products having been first of all removed as completely as possible by washing with distilled water for determination of the alkalinity. In extreme cases, glasses may be found to be covered with gelatinous or flaky material which contracts and partly scales off on drying. Since this yields alkali to water, it affects both the alkalinity and the residue on evaporation, and should therefore be removed and estimated separately. It is extremely difficult to do this satisfactorily, but drying at 100°, followed by desiccation in a vacuum over sulphuric acid, is generally effective. To avoid this lengthy procedure, an endeavour has been made to determine the amount of removable material by subjecting the tested articles to the abrading action of wet, graded sea-sand. The articles are dried and weighed after the autoclave test, treated with sand, and again dried and weighed. A blank test with the sand is conducted on an article of similar shape and composition which has previously been tested in the autoclave and cleaned in this manner, and it is found that if all the conditions are carefully standardised the method, although not of the highest accuracy, gives reasonably good results.

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* Full details of the varied durability tests employed, together with analytical data, are given by Cauwood, English, and Turner, *loc. cit.* The over-all order of durability given above was derived as described by the present author, *loc. cit.*, 90.

† Durability was determined by subjecting the glasses to the action of water vapour below and above 100° for various periods. The methods employed and criteria adopted are described, with analytical results, by Baillie and Wilson, *loc. cit.*, 50, 52T.

It is difficult to agree with Peddle * that the gelatinous matter may be ascribed to the formation of aluminosilicates. Not only is it the case, as has been found also by Turner,† that gelatinous decomposition products may be given by glasses containing only negligible amounts of alumina, but they appear to form the more readily the less alumina is present, while in the case of glasses containing much alumina this effect has not been observed in tests of considerable stringency.‡

The residue on evaporation affords less decisive information than alkalinity and clouding, unless the conditions of test have been very severe. The residue obtained from the filtered washings should be sulphated before weighing, since otherwise the mode of combination of the bases (notably the alkalis) and the degree of hydration of the silica are alike uncertain.§ Change in the weight of the test specimen is the least useful of the criteria. In general, large gains and losses alone are significant.

The Correlation of the Results and of Durability Criteria.

It is found that the first three of these criteria of durability give substantially identical information, and only slight discrepancies have been encountered. The results given by this test, therefore, possess a high degree of definiteness. In this respect, the test compares well with certain others, for example, the system of grading optical glasses by means of the iodoeosin reaction.‖ The five grades (h_1–h_5) recognised in this test depend on the weathered alkalinity of the glasses, but it is recognised that this may be less significant than change of alkalinity on weathering and, in any case, that iodoeosin values must be interpreted in the light of analytical results. Since there is no guide to the relative weights which should be assigned to the weathered alkalinity and the difference between this and the natural alkalinity, it will be seen that the iodoeosin test may yield results somewhat less critical than its notation may suggest.

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* This Journal, TRANS., 1920, **4**, 15. † *Loc. cit.*, 32.

‡ Baillie and Wilson, *loc. cit.*, 52T.

§ *Ibid.*, 49T.

‖ For a description of the original method, with references and improvements, see Jackson, *loc. cit.*, 13–25.

Not only are the first three criteria of durability closely correlated, but it has already been found, in the case of various grades of chemical glass in a series of autoclave tests at 4–8 atmospheres and lasting from one to four hours, that although a few minor changes in relative durability were encountered, the order of durability was substantially the same by all criteria; that is, that close correlation obtains within a wide range of test conditions.* Results by this test have also been found to agree closely with those of others; for example, alkalinities and degrees of clouding in excess of certain values are invariably associated, in another test, with the liberation of sufficient alkalinity to affect phenolphthalein. It has already been shown that, for apparatus glass, the autoclave test gives results in good agreement with those of the Dimming test,† while the results with the latter, in turn, are fairly closely correlated with iodoeosin values.‡

The Acceleration of Corrosion.

The corrosion of glasses may be considerably accelerated by increase in temperature, pressure, or both. The effect of each factor on the course of the decomposition may now be considered.

Chemical reactions are accelerated by increasing temperature, velocity constants usually doubling for each 7–10° elevation. It therefore follows that, in testing any series of glasses, differences may be expected to become more marked as the temperature is increased, and this is well known to occur.§ Beyond a certain point, however, impairment of discrimination is to be expected, for the conditions must eventually become so severe that glass after glass will completely fail until eventually all become indistinguishably bad. Such conditions are not difficult to attain in the case of certain glasses of low durability, and their attainment in other cases is only a matter of the strength of the autoclave employed. The practical conclusion is that no advantage is to be gained by unduly raising the test temperature and that every type of glass should be tested under conditions sufficiently severe to simplify adjudication, but not so exacting as to lead to complete breakdown.

* Baillie and Wilson, *loc. cit.*, 47–51T.

† *Ibid.*, 50T.

‡ Elsden, Roberts, and Jones, *loc. cit.*

§ Way, Cauwood, and Turner, this Journal, TRANS., 1917, **1**, 144; Cauwood and Turner, this Journal, TRANS., 1918, **2**, 260.

It is recognised that increase in temperature does not accelerate the action of superheated steam on all glasses to the same extent. This might reasonably be ascribed to water reacting with different types of glass at different rates, and a considerable body of evidence might be held to justify this explanation. There is reason, however, from the results of Mylius and Förster,* to believe that this is only partly correct, and that the hydrolytic decomposition of glasses is the result of at least two reactions which proceed simultaneously, but which are differently accelerated by rise in temperature. This conclusion derives considerable support from certain observations of Mylius,† who found that the molecular ratio Na_2O/SiO_2 in the solutions obtained by acting on a glass with water varied from 0·36 at 100° to 3·1 at 10°. It now becomes clear that not only will the alkalinity–temperature curves for different glasses vary in steepness, but that they may even intersect. Mathematical treatment of this assumption on the basis of the monomolecular reaction equation leads to curves very similar to those actually obtained in practice, which, depending on the choice of the necessary constants, may show intersections. Fluctuations in relative durability are therefore inevitable when a series of glasses is tested at different temperatures and are simply a consequence of temperature elevation. This phenomenon is naturally not in question when a single test temperature is employed, but it undoubtedly gives information of value, and it might, on occasion, be advantageous to replace the ordinary single determination of alkalinity by ascertaining the variation of alkalinity with temperature, a course in some measure analogous to the modern practice of constructing viscosity–temperature curves for lubricating oils instead of determining viscosity at one arbitrarily selected temperature alone.

Autoclave tests are unique in respect of the variable-pressure factor they afford. Precise information is lacking regarding the effect of pressure alone, but it cannot be doubted that, up to a point, like elevation of temperature, increase in pressure will accelerate corrosion. Assuming, with Förster,‡ that the first stage in the decomposition of glasses by water is hydration (physical or chemical) of the surface layer, it is clear that increase of pressure must favour attack. Beyond a certain pressure, however, which is possibly specific for each glass, it is likely, as Turner has pointed out § on the results of tests in which water and steam were used together, that certain reactions may be promoted which do not proceed to any extent at, or near, atmospheric pressure. It is therefore conceivable that alkali liberated at the earlier stages may interact with the other initial decomposition products, or with the hydrated layer, to form substances which, on washing with water, will fail to liberate as much alkalinity as is obtainable in less severe tests. This would appear to explain the observation of Hodkin,* who found, on testing a glass rich in alkali, that the alkalinity was greater at 5 than at 25 atmospheres. This reversal of effect is clearly highly undesirable, and testing conditions should not be sufficiently severe to introduce it. As was seen earlier with regard to temperature, therefore, there is no advantage, but actually positive disadvantage, in unduly increased stringency. It is not thought, however, that reversal of decomposition is to be anticipated at such pressures as have proved suitable, in practice, for testing particular types of glass. The accelerating effect of moderate pressure is considered valuable, and the fact that autoclave tests may not always reproduce exactly the relative gradings of boiling-water or other tests is regarded, apart from the possible temperature complication, not as invalidating this method, but as indicating that the other tests have not been sufficiently severe to afford full evidence of the tendency of the glasses to become hydrated and decomposed. It will be clear that the pressure factor is vital in testing glassware destined to come into contact for prolonged periods with hot water and steam.

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* *Zeitsch. Instrumentenkunde,* 1891, **11**, 311.

† *Ibid.,* 1888, **8**, 267.

‡ *Ber.,* 1892, **25**, 2494; 1893, **26**, 2915; *Zeitsch. Instrumentenkunde,* 1893, **13**, 1457.

§ *Loc. cit.,* 39.

The increased sharpness of discrimination obtainable by simultaneous elevation of temperature and pressure is exemplified below, the results being obtained in a series of one-hour tests in an atmosphere of steam at various pressures.†

TABLE III.

Reference No.	Mg. of Na_2O per sq. dem. liberated on testing at		
	2 atmos. (121°).	4 atmos. (144°).	6 atmos. (159°).
204	0·03	0·11	0·12
205	0·02	0·04	0·03
206	0·23	0·78	1·06
207	0·22	0·45	0·79
224	0·03	0·03	0·07
225	0·05	0·26	0·28

It will be seen that the glasses fall into two main groups by the 2-atmosphere test, that only two glasses are substantially equal in the 4-atmosphere test, while at 6 atmospheres all the glasses are completely distinguished by the criterion adopted.

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* Quoted by Turner, *loc. cit.*, 38.

† Baillie and Wilson, *loc. cit.*, p. 47T.

Conclusions.

It will be seen that our knowledge of the kinetics of the reactions occurring when glasses are corroded by steam at high temperature and pressure is by no means complete, and that the several effects of temperature and pressure will eventually give rise to highly complex phenomena. This, however, does not occur until the conditions are much too severe for the glasses under test, unless, of course, due attention has not been directed in the first place to the selection of testing conditions, and in practice, the results of the autoclave test have been found simple of interpretation.

The multiplicity of procedures already described in the literature of glass-testing and the fact that correlation of results is generally extremely difficult have recently been emphasised in this JOURNAL.* The author is of opinion that should the question of a standard test be considered, as has been suggested, by the Glass Standards Committee of the Society, the advantages of the autoclave test are sufficient to warrant its careful consideration. It is not thought, however, that one set of conditions could advantageously be specified, since this course would inevitably lead to results of doubtful value. It would appear that the principle governing durability tests for glasses is that the conditions should be sufficiently severe to afford sharp discrimination, but that much greater severity is detrimental. It is believed that satisfactory conditions can be established for commercial glassware of all degrees of durability, and that, although other or more vigorous conditions may be useful in control or investigation, the three tests described above should prove adequate for general purposes.

The author desires to thank Mr. G. H. Perry, O.B.E., Director of Chemical Inspection, for the interest he has taken in this question, and is indebted to the Director of Artillery, War Office, for permission to include in this paper results obtained in the work of the Glass Laboratory.

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† Turner, *loc. cit.*, 42.

XXIV.—*Some Criticisms on the Use of the Autoclave as a Method of Testing Glassware.*

By W. H. Withey, B.A. (Cantab.).

(*Read at the London Meeting, December* 13*th*, 1922.)

The importance of the power of glass to withstand the action of water in its various forms and at different temperatures has been recognised by most investigators as one of the most useful means of judging the suitability of glass for its several uses.

The methods employed have been very varied, and owing to the small amount of attack on good glasses, attempts have been made to make the conditions more severe in order to obtain more decisive results, and to avoid reliance on extremely delicate reagents which require very skilled experience.

Among such methods one which has recently come into prominence consists in subjecting the glassware to the attack of water and steam under high pressure. There is little doubt that such a test is open to no possible objection in the case of such articles as water-gauge tubes, or other glassware, which in practice will be subjected to conditions of this nature, but on the other hand if the glass is never likely to be subjected to such treatment, a test of this nature is at the best very drastic and possibly somewhat unfair. For example, a glass which is never likely to be used for temperatures exceeding 100° and has by other tests proved to be satisfactory in practice, might conceivably compare less favourably with another glass at the higher temperature, whereas at 100° there is no pronounced difference between them.

This point receives support from the observation which was made by Foerster in his classic researches; he noticed that glasses which showed little or no difference in resistance at, say, 20° might at 80° show greater disparity and in some cases the relative positions of the two glasses might be exchanged. No explanation of this phenomenon was given; and it does not seem impossible that under other and more drastic attack the two glasses might again change places. It naturally follows that the two glasses may be equally good if used under the conditions which best suit their special idiosyncrasies.

In applying the autoclave test, it is also a matter of regret that various workers have not employed a uniform standard as regards pressure and time of exposure. Very few data appear to have been published which enable one to judge of the rate of attack, or the result of successive and prolonged periods of exposure to the same conditions.

In the course of some tests on two varieties of resistance glass, the author made some experiments on the latter question, and as a result certain weak points in the autoclave method were revealed.

The two glasses in question were of different composition, one being a zinc and the other a lime borosilicate. On subjecting the vessels to an autoclave test at four atmospheres pressure for a period of three hours, it was noticed that one of the zinc borosilicate vessels had a very slight but distinct bloom which on gentle friction could be removed, thin flakes of decomposed glass becoming detached in the process. The lime glasses were also "bloomed," but in this case the deposit withstood all attempts to remove it.

The alkalinity of the water in each beaker was determined and also the total solid matter removed in solution.

Another test was made on the uncleaned vessels for the same period, at the end of which it was noticed that only with the greatest difficulty could the deposit on the zinc glass be retained *in situ*, but with the lime glass the deposit was very coherent and more pronounced than at the end of the first period. It was therefore perfectly clear that the test was not equally fair to both glasses, as in one the water could readily get behind the deposit, while in the other case the attack must proceed through the debris from the previous test. In the first case, new and unattacked glass was subjected to test, while in the other conceivably a disintegrated and somewhat insoluble residue would be under investigation. We should therefore anticipate that the zinc glass would give under each successive period very similar results, while in the case of the lime glass we might reasonably expect the soluble extract to become smaller in succeeding periods owing to the fact that the coherent disintegrated scales would become less readily attacked by the water.

The test on the two varieties of glass at the end of the first period indicated that in three hours both glasses had been attacked, and if it had been possible to stop the test at intervals during the second three-hour period and examine the amount of attack, it would probably have been found that for a time the soda–lime glass had rapidly become less resistant and had in the process developed a characteristic protective coat, whereas the zinc glass owing to the sloughing propensity of the decomposed layer exposed fresh layers of glass to the attack, which in consequence would proceed regularly. As a result, at the end of the second period, the total degree of attack indicated that the soda glass did not compare so favourably with the zinc glass as at the end of the first period. During the third period, on the other hand, the lime glass having now a well-developed and somewhat insoluble layer, the degree of attack again became less, in consequence of which the difference between the two glasses at the end became more of the same order as at the end of the first interval.

The conclusions to be drawn from these observations are that to make the autoclave test really trustworthy it is imperative by some means or other to determine the effects of the attack at different pressures and at comparatively short intervals of time, as by such means only is it possible to trace the progress of disintegration.

The method requires a good deal more research, and if work on the lines indicated could be carried out the results so obtained would give more valuable information than is possible under the present arbitrary conditions.

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XXV.—*The Action of Water and Steam under Pressure on Some Soda–Lime–Silicate Glasses.*

By F. W. Hodkin and W. E. S. Turner.

This paper records the results of some experiments made between two and three years ago on the action of water and steam under pressure on three sets of soda–lime–silicate glasses. It was intended at the outset that experiments should be carried out at pressures rising up to 50 and 100 atmospheres pressure, and perhaps even higher pressure still, in order to check the very interesting results obtained by Barus [*] in 1899.

Our own work was interrupted and no opportunity has yet arisen to continue the investigation with pressures beyond an excess pressure of 25 atmospheres, that is, approximately, 375 lb. per square inch. The results obtained, however, are of some interest in themselves; may be usefully compared with those recently obtained by A. E. Williams [†] and by K. L. Ford [§] on the action of water and steam on soda–lime glass containers; and, finally, are worthy of study since they illustrate some of the difficulties which beset the use of the autoclave in testing the durability of glass.

Four series of glasses were specially prepared for the purpose of the experiments, their compositions corresponding approximately with the following molecular formulæ :

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[*] C. Barus, *Amer. J. Sci.*, 1899, **47**, 461; *Phil. Mag.*, 1899, **47**, 461.

[†] *J. Amer. Cer. Soc.*, 1922, **5**, 504.

[§] *Ibid.*, 837.

(1) $6SiO_2,0{\cdot}3CaO,1{\cdot}7Na_2O$ (2) $6SiO_2,0{\cdot}7CaO,1{\cdot}3Na_2O$
(3) $6SiO_2,0{\cdot}8CaO,1{\cdot}2Na_2O$ (4) $6SiO_2,CaO,Na_2O$

The samples of glass were prepared in the form of discs approximately 6·3 cm. in diameter with a total surface area of about 80 to 96 sq. cm. The discs were cast but were not polished. They were annealed before being subjected to the test.

Previous experience had shown us that whereas glasses of the soda–lime–silicate type might withstand the action of boiling water quite satisfactorily, in some cases they readily broke down under treatment with water and steam under pressure. One of the objects of the experiments was to ascertain at what stage this breaking down took place rapidly.

In carrying out the tests, simultaneous experiments were made both of the action of water and of steam. Two discs of the same glass were employed. One of the discs was immersed in water contained in a platinum dish, and the basin covered with platinum foil. On this foil three platinum wire points supported a second disc so as to be subjected only to the action of steam. The upper disc was protected by another platinum dish suspended over it.

The temperature and pressure were then raised to a definite value, tests being carried out at a series of pressures between 2 and 25 atmospheres. In each case the pressure was maintained at its maximum amount for three hours. The time needed to reach the maximum value increased with the pressure as also did the time of cooling down to the atmospheric pressure. These values, expressed in minutes, are, for all glasses except the $6SiO_2O,3CaO,Na_2O$, as follows :

Excess pressure (atmos.) . .	2	4	5	7·5	10	12·5	15	17·5	20	22·5	25
Time of heating to maximum .	45	50	50	55	60	60	60	65	65	85	95
Time of cooling .	60	80	95	105	115	125	130	135	150	165	175

Slightly different times only were observed for the remaining glass.

At the end of the treatment the discs were rinsed in water, wiped dry on a cloth and placed in a desiccator and subsequently weighed. In one set of experiments, namely, those with the glass of the composition $6SiO_2,CaO,Na_2O$, the alkaline solution obtained by the action of the water was titrated, using methyl-orange as indicator, in order to obtain a measure of the corrosion in addition to the loss in weight.

General Appearance.

Glasses of the Composition $6SiO_2,0{\cdot}3CaO,1{\cdot}7Na_2O$.

Even at 2 atmospheres excess pressure the slab immersed in water had broken into five pieces, and each of these pieces was pitted and cracked so that splinters were produced. The attack was worst on the mould marks on the under-surface of the slab and round the edges, whilst at certain points distributed over the surface the glass had been noticeably attacked, producing a cluster of crystal-like formations which stood out as a growth on the glass. These prominences were readily removed by washing.

The action of steam was also to break the slab and to produce an attack similar to the water.

The action both of water and of steam at 4 atmospheres was similar in general character to that at 2 atmospheres, the glass exposed to water developing a surface with an embossed appearance. Small, rounded projections, completely covering the upper surface, as if they constituted points of harder texture than the remainder were also developed. An opalescent scum was present on the surface of the slab, but was removed by gentle rubbing.

At 5 atmospheres a white coating was produced over the whole of the slab, most of it coming away on subsequent washing, but a portion of it adhering firmly. This residual coating became granular after the disc was dried.

In steam, a somewhat similar action occurred, but there was also pitting in isolated spots and deep erosion in lines in some cases, the grooving being an inch in length. These lines of erosion appeared only on the under-surface of the slab; that is to say, on the surface which had been in contact with the mould when the disc was cast.

At 7·5 atmospheres the attack on the disc due to water resulted in the formation of a thick, white coating, star-shaped cracking on the under-surface of the disc and along the line of breakage, since the disc was split. Pitting in lines also occurred, whilst the edges of the disc assumed a weathered appearance which might be described as mouse-eaten.

In steam, the attack was somewhat similar.

At 10 atmospheres pressure the general appearance of the discs treated both with water and with steam was similar to that at 5 atmospheres pressure.

At all pressures between 15 and 25 atmospheres a new phenomenon made its appearance. There was in each case, in addition to the white decomposition layer formed, a second film, tough and jelly-like, giving the slab a pinkish appearance. In some cases this jelly-like film could be removed by rubbing, the residual glass having

TABLE I.

Pressure.	$6SiO_2,0{\cdot}7CaO,1{\cdot}3Na_2O$.		$6SiO_2,0{\cdot}8CaO,1{\cdot}2Na_2O$.		$6SiO_2,CaO,Na_2O$.	
	Water.	Steam.	Water.	Steam.	Water.	Steam.
2	—	—	—	—	No attack.	No attack.
2·5	Pitting and splintering.	As in water but less extensive.	No marks whatever.	No marks whatever.		
5	Pitting and splintering more extensive than at 2·5 atmos. Points of attack larger.	Pitting and splintering slight. Thin scum over surface — hard and resistant.	No marks whatever.	No marks whatever.	No markings very definite. Very slight filming in parts.	As in water.
10	Film over surface, particularly under surface. Pitting and splintering less than at 5 atmos.	Only slight filming, but more pitting and splintering at many places.	Pitting and splintering in pin-head spots. Filming general. Whole surface slightly dimmed.	As in water but less intensive.	Filming general. Surface dimmed. No pitting.	As in water.
15	Thin film — washed off easily; pouring lines clearly defined by attack. Slight pitting. *Duplicate*: Thin powdery film—etched appearance.	Filmed—did not all wash off. Slight pitting. *Duplicate*: Thin film—peeled in large glassy scales.	As 0·7CaO. In a second test the pouring lines were clearly defined on under surface.	As 0·7CaO, but filming not so extensive.	Very similar to results at 10 atmos.	As at 10 atmos.
20	Thin film. Pitting but no splintering.	Filmed in parts—pitting but no splintering.	Whole surface dimmed. Pouring lines clearly defined all over. Slight pitting.	As in water.	Opaque — white film. Almost entirely removed by washing. Surface remained rough with milky appearance. Mould marks well defined.	Attack as at 10 atmos., but slightly more intense.
25					As at 20 atmos.	Very thin resistant film on surface —apparently no marked attack.

an embossed appearance as well as pits. There was no essential difference between the action of water and steam in all these cases.

The results with the three other glasses may conveniently be summarised in Table I, p. 294.

Some of the visual effects of the corrosion are illustrated in the accompanying photographs taken full size.

Figs. 1—6 are photographs of the glass discs of composition $6SiO_2,0{\cdot}3CaO,1{\cdot}7Na_2O$ after treatment. In Fig. 1, the action of water at 10 atmospheres more particularly on the upper surface is shown, the curved and winding corrosion lines being the pouring lines when the glass was cast. Pitting is considerable. The deep scorings seen are on the under side of the disc.

The effect of steam at the same pressure is shown in Fig. 2, the photograph being of the upper surface. Part of the adhering white film is shown, and the pouring lines again are evident.

Fig. 3 is of the under surface after treatment with water at 20 atmospheres pressure. The disc was cracked across and deep, rough groovings produced. These groovings are roughly parallel and form arcs of concentric circles.

The roughened surface shown in Fig. 4 is left after cleaning away the surface film and the gelatinous layer after the action of steam at 20 atmospheres. The photograph shows also the reduction in size of the disc through material lost by the treatment.

Figs. 5 and 6 show the action of water and steam, respectively, at 25 atmospheres. The embossed and pitted appearance when the gelatinous layer was removed is revealed.

Figs. 7 and 8 are photographs of discs of the glass

$$6SiO_2,0{\cdot}7CaO,1{\cdot}3Na_2O.$$

The effect of water at 5 atmospheres produced pitting on the upper surface (Fig. 7).

The way in which corrosion follows the pouring lines is beautifully brought out by Fig. 8, which is a photograph of the same glass subjected to water at 15 atmospheres pressure. The course of the tailing which completed the pouring from the gathering iron and sank into the body of the glass is clearly indicated.

Figs. 9, 10, and 11 are of samples of the glass containing 0·8 molecule CaO, the agent being water in each case, the pressures being 5, 10, and 15 atmospheres, respectively. Pitting on the upper surface at 5 atmospheres (Fig. 9) was very slight, but was pronounced at 10 atmospheres (Fig. 10). The filming and the corrosion along the pouring lines when the pressure was 15 atmospheres are shown in Fig. 11.

The outstanding feature appears to be that the cracking, splintering, pitting, grooving, etc., most readily occur in the least durable glasses, the cracking occurring at quite small water- and steam-pressures with the glass containing only 0·3 of a molecule of CaO (that is, approximately 3·5 per cent. and 21·8 per cent. of Na_2O). With the glasses containing 0·8CaO and 1·0CaO (that is, approximately, 9·4 and 11·75 per cent. of CaO) either only very slight or no markings at all were found after treating them at pressures up to 5 atmospheres (or 75 lb. pressure in excess of atmospheric).

The corrosion, which appears to be associated with physical condition, cannot be dissociated from the general chemical durability of the glass. Thus, the evidence of corrosion along the pouring lines (that is, along the lines of the rope of glass which streamed down from the gathering rod into the mould), required, generally speaking, treatment of the glass at a higher pressure as the percentage of lime increased and that of the soda diminished.

We have previously directed attention to the phenomena of cracking, splintering, pitting, and the development of corrosion along the pouring lines when discs of soda–lime glasses are boiled for six hours in water.* Haigh, working with Jackson,† also found, in pieces of glass subjected to weathering, portions of greater and less durability, some spots being but very little attacked. Such results are also in accord with our own observations; for example, as we have already stated, when the glass containing 3·5 per cent. of lime was treated with water or steam at 4 atmospheres pressure, small rounded projections, apparently of harder texture, were left on the glass.

In keeping with these observations, we have the results obtained by A. E. Williams from his study of the corrosion of glass containers. Of particular interest was his observation that in pressed and in pressed and blown machine-made containers the chipping and spalling which occurred on treatment with water were found in almost every case on the exterior only and might be associated with some influence of the surface of the mould—although in pressed glassware one might have expected similar phenomena on the interior which had been in contact with the plunger.

We have pointed out that grooving, in our specimens, occurred, not on the upper surface of the disc as cast, but on the bottom, which had been in contact with the mould.‡

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* Report Brit. Sci. Instrument Research Assoc., 1921.

† Cauwood, Clarke, Muirhead, and Turner, this Journal, Trans., 1922, 3, 228.

‡ We do not suppose that contact with the platinum dish can have been liable for these groovings, but we propose to test the assumed effect of the mould on the glass surface by making some experiments in which the upper surface of the disc is placed in contact with the platinum dish whilst the moulded surface is uppermost.

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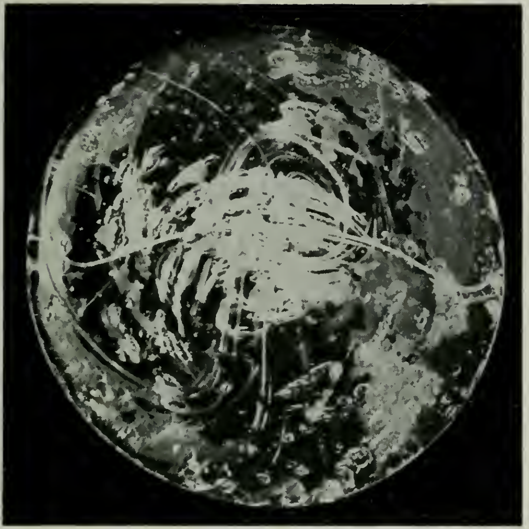

Fig. 1.

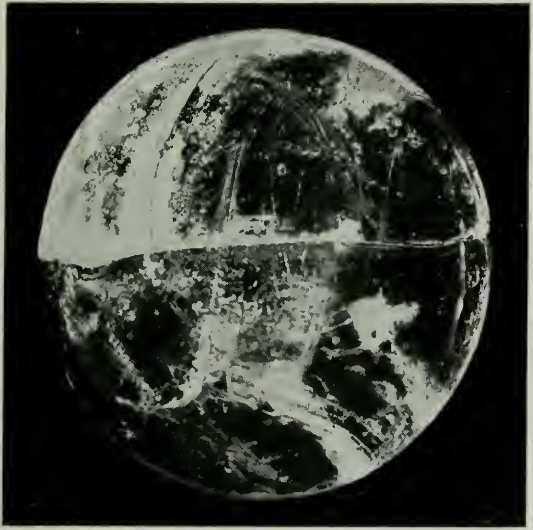

Fig. 2.

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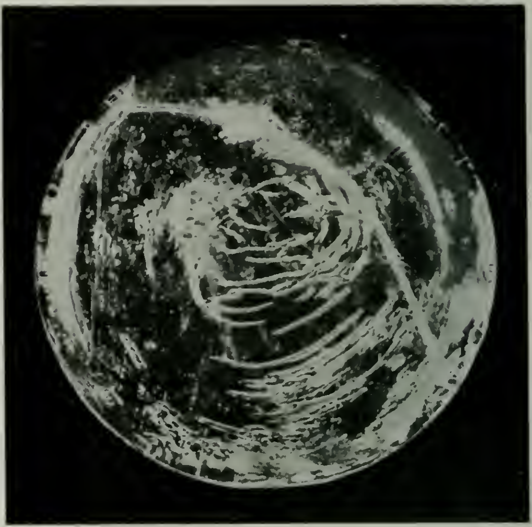

Fig. 3.

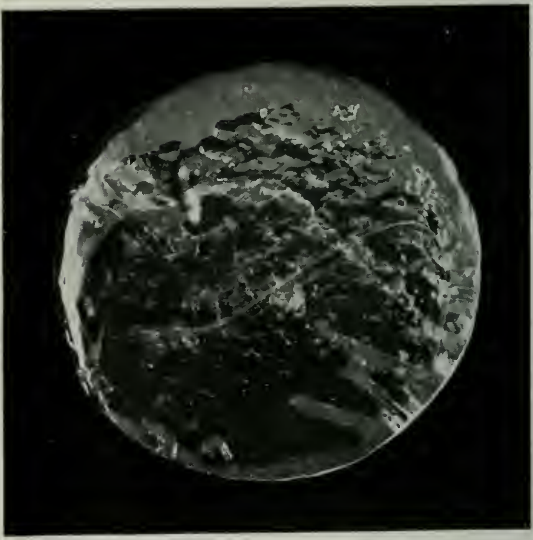

Fig. 4.

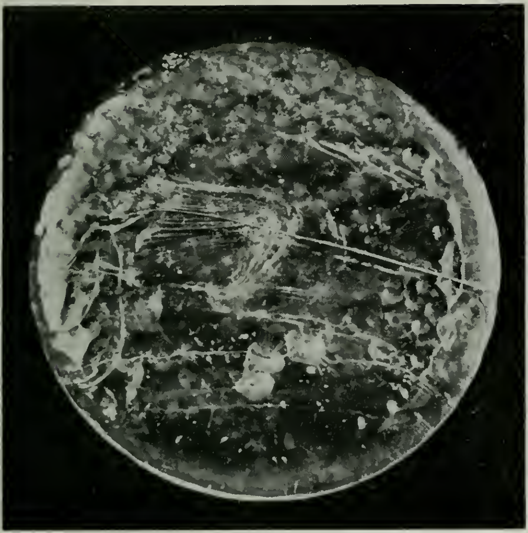

Fig. 5.

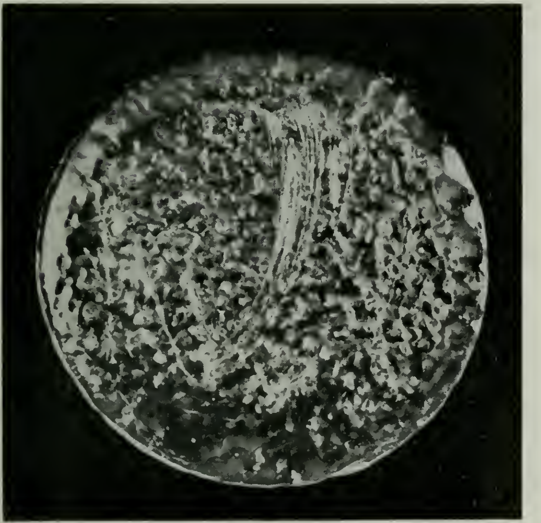

Fig. 6.

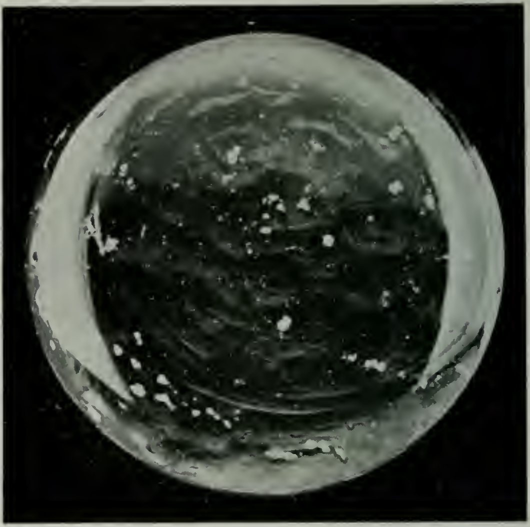

FIG. 7.

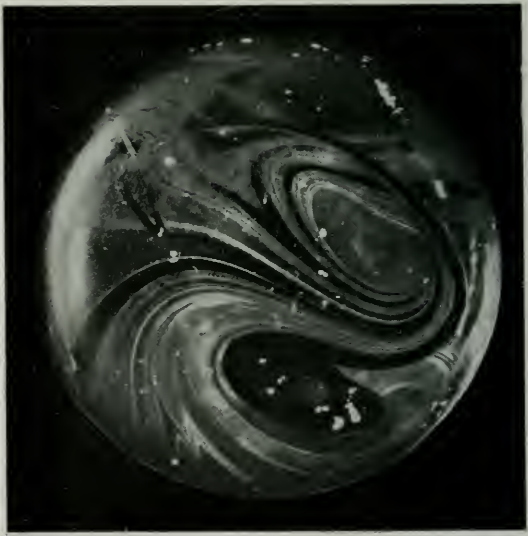

FIG. 8.

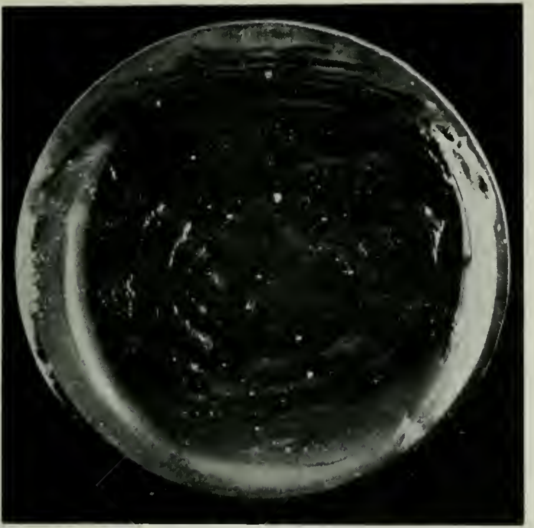

FIG. 9.

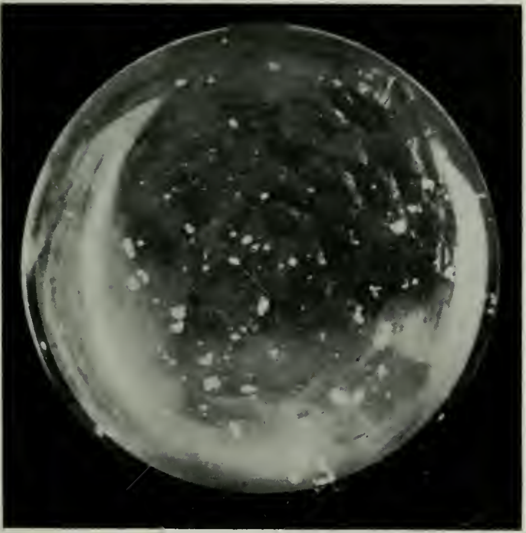

FIG. 10.

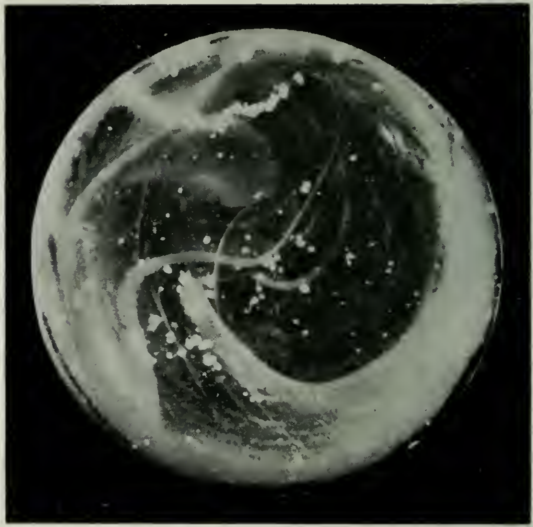

Fig. 11.

It is of interest to note also that Williams observed one example of a glass container in which the corrosion occurred along the pouring lines, as in our own experiments and the reference of J. A. Knowles * to the corrosion in arcs of concentric circles, of mediæval crown glass, is particularly valuable in this connection. It would be of great interest to know whether or not such corrosion occurred on both faces of the sheet, or only on that which, in cylinder form, came into contact with the mould or shaping block.

Knowles also refers to the pitting seen on the *interior* of glass jars. We have ourselves noted that pitting occurred first on the *upper* surface of the glass discs and not on the surface originally in contact with the mould. Preferential pitting, such as is to be observed in old window glass is also probably determined by the character of the surface, and further experiment may find an explanation for it.

The Extensiveness of Corrosion at Various Pressures.

The results of the action of water and of steam in the case of each glass are stated in the tables II, III, IV, and V below.

TABLE II.

The $6SiO_2,0{\cdot}3CaO,1{\cdot}7Na_2O$ *Glasses.*

Excess pressure (atmos.).	Water. Loss in wt. (gms. per 100 sq. cm.).	Gms. of Na_2O extracted per 100 sq. cm.	Steam. Loss in wt. (gms. per sq. dcm.).
2	0·8814	0·1011	0·3352
4	2·887	0·1888	2·207
5	4·897	0·8390	2·808
7·5	6·668	1·067	6·723
10	13·69	2·344	13·32
15	28·90	4·252	14·80
20	31·66	4·738	40·03
25	33·78	4·835	42·45

TABLE III.

The $6SiO_2,0{\cdot}7CaO,1{\cdot}3Na_2O$ *Glasses.*

Excess pressure. (atmos.).	Water. Loss in weight. (gm. per 100 sq. cm.).	Steam. Loss in weight. (gm. per sq. dcm.).
2·5	0·0042	0·0030
5	0·0152	0·0062
10	0·0870	0·0425
15	0·0719	0·7993
15	0·0675	0·3339
20	0·1239	0·0830

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* This Vol., TRANS., p. 258.

TABLE IV.

The $6SiO_2,0{\cdot}8CaO,1{\cdot}2Na_2O$ *Glasses.*

Excess pressure (atmos.).	Water. Loss in weight (gm. per 100 sq. cm.).	Steam. Loss in weight (gm. per sq. dcm.).
2·5	0·0034	0·0011
5	0·0154	0·0024
10	0·0767	0·0175
15	0·1115	0·0493
15	0·0817	0·6933
20	0·1155	0·0257

TABLE V.

The $6SiO_2,CaO,Na_2O$ *Glasses.*

Excess pressure (atmos.).	Water. Loss in wt. (gm. per 100 sq. cm.).	Gm. Na_2O extracted per 100 sq. cm.	Steam. Loss in wt. (gm. per sq. dcm.).
2	nil.	nil.	nil.
4	nil.	nil.	nil.
5	0·005	0·0080	0·003
7·5	0·018	0·0453	0·045
10	0·038	0·1143	0·040
12·5	0·024	0·0579	0·082
15	0·054	0·1639	0·036
17·5	0·086	0·2247	0·083
20·0	0·118	0·3411	0·117
22·5	0·100	0·2372	0·013
25	0·117	0·3353	0·009

A survey of the above tables reveals a number of irregularities; that is to say, the losses in weight as the pressure increases do not always rise in the regular manner expected. Most of these irregularities, however, have their explanation, which will be referred to below. The discussion may suitably be divided into sections.

I.—*The Relative Action of Water and Steam.*

Our experience in the testing of all types of chemical glassware has previously shown us that the soda–lime–silicate glasses differ in a very marked manner from those containing considerable proportions of alumina, boric oxide, and zinc oxide, in that whilst the latter are but comparatively little affected by steam in comparison with the effect of water, the former are affected to a very great extent by steam as well as by water.

That this is so is clear from the figures set out in the above tables. In some cases, indeed, the action of the steam seems greater than that of water, this especially being the case at the highest pressures employed in the case of the least durable glass, namely, $6SiO_2,0{\cdot}3CaO,1{\cdot}7Na_2O$. Even with the comparatively durable glass $6SiO_2,CaO,Na_2O$, which suffered no loss of weight either through the action of steam or of water up to 4 atmospheres pressure, and gave no appreciable amount of alkali to the water, the loss in weight caused by the steam at 7½ atmospheres is about 2½ times that due to water.

The irregularity in the numerical results obtained makes quantitative comparison difficult, and we do not propose to make the attempt. It is clear that in the case of the least durable glass the total loss in weight due to the action of water was much greater than the amount of alkali extracted from the glass, in most cases six to eight times as much. In the case of the more durable glass, $6SiO_2,CaO,Na_2O$, however, the amount of alkali extracted was in every case greater than the total loss in weight, showing most probably that at 5 atmospheres pressure or more, a considerable water absorption occurred in this glass, whilst in the least durable glass the magnitude of the loss in weight compared with the alkali liberated could be explained by erosion and shattering of the glass surface, the detritus only being to a slight extent decomposed chemically. It is also interesting to note that with steam the loss in weight increased from 5 atmospheres up to 20 atmospheres pressure and then rapidly fell off, showing clearly that beyond 20 atmospheres the absorption by the glass of water due to the action of steam under pressure increased very much more rapidly than the loss in weight.

II.—*The Influence of Composition on the Extensiveness of Corrosion.*

From an examination of Tables II to V it is clear that the glass $6SiO_2,0{\cdot}3CaO,1{\cdot}7Na_2O$ is far and away the most readily corroded by water and by steam, whilst the glass $6SiO_2,CaO,Na_2O$ (allowing for some irregularities at high pressures, 20 to 25 atmospheres) is the most durable. So much, of course, has already been proved by boiling water tests.*

Up to 4 atmospheres pressure no action is discernible on the glass $6SiO_2,CaO,Na_2O$.

The glass of low lime content differed from the three others in that a gelatinous mass was produced below the white incrustation at pressures of 15 atmospheres and more, whilst the crust obtained, generally speaking, was harder the more lime the glass contained. The glasses of low lime content also readily underwent fracture when treated with water and steam under pressure. We have observed this frequently in the case of bottles and containers which have been manufactured with an excess of sodium oxide present and a deficiency of calcium oxide, cracking, starring, pitting, and splintering all being typical of such glasses when boiled in water or treated with water and steam under pressure.*

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* Cauwood, Clarke, Muirhead, and Turner, this Journal. TRANS., 1919, **3**, 228.

The Use of the Autoclave as a Means of Testing the Durability of Glass.

The action of water and steam under pressure has been advocated by several workers as a rapid method of ascertaining the durability of glass. It is recommended, for example, by the Institute of Chemistry Committee,† whilst Wilson and Baillie even advocate the use of steam under pressure as a single distinguishing test. We find it difficult, as the result of our own experience, to be so enthusiastic about the method as the last-named authors, and our difficulties are at least four in number.

(1) The action of water and steam under pressure does not necessarily lead to the same conclusions in regard to durability as the action of boiling water. Thus, we have previously found that a glass of composition SiO_2 76·10, Al_2O_3 0·20, Fe_2O_3 0·14, CaO 6·30, MgO 0·29, MnO 0·10, K_2O 5·60, Na_2O 11·16 proved very durable in comparison with the best chemical glasses when subjected to boiling water, losing only a minute amount in weight and giving but a trace of alkali to the water. Under the action of water and steam at 10 atmospheres pressure, on the other hand, its corrosion was so remarkable as to be much the worst of any chemical glass tested. The two methods of test would obviously lead to widely divergent results. Whatever the results of the autoclave test, however, it is but common sense to believe that under ordinary laboratory treatment the glass should be very useful.

(2) The ratio of the loss in weight suffered by the glass to the alkali extracted is radically different according as the glass is treated with boiling water or with water and steam under pressure. We have already directed attention to this matter in a previous paper.‡

(3) The relative action of steam and of water varies from glass to glass, not only when the glasses are of different chemical types, but also when they are similar in type. Even with the soda–lime–silicate glasses now dealt with the relative effects differ. Modern chemical glasses containing considerable proportions of alumina, boric oxide, and zinc oxide appear to be affected but little by the action of steam. At ordinary pressure, indeed, we

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* See also A. E. Williams, *loc. cit.*

† *J. Inst. Chem.*, 1920.

‡ "A Critical Examination of the Methods commonly used in Determining the Durability of Glass." W. E. S. Turner, this vol., TRANS., p. 30.

have found that a good soda–lime–alumina–borosilicate was not affected by having steam at 500° passed over it under atmospheric pressure for two hours.

(4) The results of the autoclave test appear to be irregular, especially at pressures above 5 atmospheres, with certain types of glasses, the soda–lime–silicates in particular. We have found this to be the case, not only when the loss in weight (admittedly an incorrect basis of test) is taken as the measure of corrosion, but also when the total alkali extracted is determined. The reason for the abnormal results appears to be associated with the formation of a hard crust, probably of hydrated silicate, which retards further action and at least makes that action irregular.

It is conceivable that for pressures not greater than 5 atmospheres more concordant results may be obtained. All the evidence we have gained so far leads us to reject the autoclave as a single deciding test of the durability of glass. We would regard it as a necessary test for glass, such as boiler gauge glass, which has to withstand the action of steam and water at high pressure. In other cases, we would much prefer to rely on tests more in keeping with the treatment to which the glassware will be subjected in normal use.

SUMMARY AND GENERAL CONCLUSIONS.

(1) Four soda–lime–silicate glasses, of approximate composition,

$6SiO_2,0{\cdot}3CaO,1{\cdot}7Na_2O$; $6SiO_2,0{\cdot}7CaO,1{\cdot}3Na_2O$;

$6SiO_2,0{\cdot}8CaO,1{\cdot}2Na_2O$, and $6SiO_2,CaO,Na_2O$ have been subjected to the action of water and of steam at pressures in excess of atmospheric varying from 2 to 25 atmospheres.

(2) It was shown that the action of steam on these glasses is very considerable, being greater even than the action of water at pressures from 20 to 25 atmospheres in the case of the glass with least lime content.

(3) The extensiveness of corrosion diminishes considerably as the amount of lime is increased and the amount of sodium oxide present is decreased. At pressures of 2 and 4 atmospheres applied for three hours, no corrosion was found to be produced either by water or by steam on the glasses containing approximately 9·4 and 11·75 per cent., respectively, of calcium oxide.

(4) With the two glasses throughly tested, namely,

$6SiO_2,0{\cdot}3CaO,1{\cdot}7Na_2O$ and $6SiO_2,CaO,Na_2O$,

the loss in weight recorded was less than the total amount of alkali (Na_2O) extracted, clearly indicating the absorption by the glass of a considerable quantity of water.

(5) All the glasses tended to produce an incrustation as the

result of the action of water and of steam, the extent of this incrustation increasing, generally speaking, as the pressure increased. The greater the amount of lime present the harder the incrustation. In the case of the glass with 0·3CaO, a gelatinous layer was also produced below the incrustation at pressures of 15 atmospheres or more. The possibility, therefore, of reducing soda–lime glass to a viscous aqueous solution by treatment with water or steam at high pressure, is likely to become increasingly difficult as the lime content increases.

(6) Corrosion by water and steam under pressure, as previously shown from this laboratory and by others previously in the case of boiling water, is influenced by the condition of the surface, grooving being confined to the surface which had been formed in contact with the mould whilst the pouring lines when the glass was cast are also clearly brought out, being lines along which corrosion occurs. These results are of considerable practical interest in connection with the durability of glass vessels.

(7) The use of the autoclave as a means of testing durability does not appear to us a method to be recommended as a general single test. It is a necessary test for glass which has to be subjected to the action of steam under pressure in ordinary use, but is too severe in the case of soda–lime–silicate glasses, which are frequently quite resistant to the action of boiling water in ordinary use, although they break down readily through the action of steam and water under pressure.

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Discussion.

Mr. Stott suggested that the main effect of a change of pressure was to produce a rise of temperature, and, that being so, supposing in the autoclave a certain amount of air was left, the temperature which would be obtained would not be exactly in accordance with the standard pressure, and he would rather like to know with what certainty the temperature obtained really was the temperature corresponding with the pressure of the steam.

Prof. W. E. S. Turner said he thought it was generally found that the temperature in the autoclave scarcely corresponded with the pressure as measured on the gauge. This was the experience of Mr. Hodkin and himself in the investigation described and he believed Mr. Baillie had had similar experience. The high pressure was important, quite apart from the temperature corresponding; for if, as he had previously argued, the first process in the corrosion of glass by water was the absorption of the latter by the glass, then this absorption (or "adsorption") was a function of the pressure.

Dr. M. W. Travers expressed the hope that some simplification of the durability test might be arrived at on the lines suggested by Prof. Turner, because in the long run it would be found necessary to make the test fit the particular purpose, but the difficulty in connection with powdered glass was that they did not know exactly what surface they were dealing with, especially when different people ground the glass. In the ordinary course of practice they did not boil anything continuously in a beaker for more than an hour or two at the outside, and he would therefore suggest testing beakers by boiling water or acid in them for forty-eight hours. For Petri dishes, the autoclave test was the correct test, but only low pressures should be applied. With regard to soft lamp-working glass, the autoclave test was too severe. For a suitable lamp-working glass they must have 15 to 18 per cent. of alkali, and such glass would not withstand water at above 100°.

Mr. E. A. Coad-Pryor endorsed all that Prof. Turner had said, and added that, having been in touch with the manufacturers of all classes of glass, he felt it was vitally important to get down to a standard test as quickly as possible, in the interests of both users and manufacturers. His experience was that glass users were very quick to insist on glass complying with certain tests. He had, in fact, been asked for glass which would stand the autoclave test, and when he had said, "What autoclave test?", the reply had been, "Is there not an autoclave test which sorts out the sheep from the goats?" It was very clear that the user who was so quick on the up-take as that, if he saw the average test for bottles was 30 lb. for two hours, would probably say he wanted a better bottle than would stand the average test, and might possibly ask for 50 lb. In these circumstances, it would be a good thing if the Standardisation Committee of the Society took the matter up and came forward with an authoritative opinion on the whole subject. The argument that the autoclave test was an easy one seemed to be a good argument against it.

Mr. E. Meigh said that, looking at the matter from the common-sense point of view, it seemed to him that Mr. Baillie and Prof. Turner were advocating the same thing, namely, that the conditions of the test should approximate as nearly as possible to the conditions of use. Apparently, Mr. Baillie advocated that the test should be modified to suit the different conditions, whilst Prof. Turner suggested that there should be a variety of tests. Both these suggestions would give a rough approximation to the practical conditions, but it certainly seemed to him that testing powdered glass with boiling water was getting no nearer to the practical state of affairs than by varying the autoclave test. In fact, of the two, the former seemed to him to be the inferior. He did not think they could disregard the condition of the surface of the various types of container they were going to test, and if they crushed the glass into a powder it was not going to help very much. Therefore, it seemed to him that they were rather chasing a will-o'-the-wisp in trying to get a standard test for all classes of glass. If the consumer was going so quickly to examine the results of the scientific deliberations of the Society, as Mr. Coad-Pryor had suggested, it almost seemed that the Society should consider very carefully whether the test to be suggested as a standard one should not be a cold water test.

Mr. Adams raised the question of testing glass articles in bigger quantities. The test they had been discussing applied to small quantities or small pieces, but a different condition of affairs arose in connection with potted-meat containers, which, after being filled, were sterilised in batches of 10 or 12 gross at a time in an apparatus which was like a low-pressure autoclave. Some of these containers, after sterilisation, exhibited a perfect surface, but others, made, presumably, from the same class of material, showed distinct signs of disintegration on the surface. That seemed to him to point to a test being arrived at, not so much from the point of view of the actual chemical composition of the glass, but from the physical condition of the glass at the time the test was made. Some twelve months ago he made tests on some containers which were used for soups, and found the same differences in the glass after sterilisation. Some of them showed distinct curved lines in the direction of the gathering, where it had been pressed out and cooled down, and he was rather wondering whether, in a case like that, there was some want of homogeneity in the glass, which defect might be revealed when large batches were tested, although the test might suffice for small pieces or small quantities. It would therefore be interesting if information were avilable as to the physical condition of the glass as affecting durability.

Mr. E. A. Coad-Pryor remarked that if a standard test were devised a standard time should be stipulated within which the articles should be examined subsequent to being made. He himself had tested meat-jars and found that, whereas the results were satisfactory shortly after the jars were made, jars which had been stored for six months prior to test came out of the test like a London fog.

Prof. Turner said that, as a matter of fact, some results were already available showing that the physical condition of the glass surface affected the durability. He would like to direct the attention of Mr. Adams to the recent papers of A. E. Williams and of Ford, published in the *Journal of the American Ceramic Society*. Moreover, the results of the studies at Sheffield also clearly brought out the influence of the surface and Mr. Adams would find interesting data in the full paper by Mr. Hodkin and himself when it was printed.

Mr. Baillie, in reply (*communicated*), said that the most valuable feature of the discussion had been the widely-expressed desire on the part of manufacturers and users alike for the general adoption of a standard method of determining the durability of glasses. The question merited consideration by the Glass Standards Committee of the Society and could be further discussed on the basis of the recommendations.

The adoption of so-called " practical " tests, as urged by several speakers, was beset with difficulties. The normal conditions of use of a few types of glassware were doubtless sufficiently definite to be reproducible as conditions of test, but this was not often possible. The results of such a test could not, in any case, be of any great utility, for only inferior articles would give rise to appreciable quantities of corrosion products. To become satisfactorily critical, such tests would require to be prolonged, repeated, or accelerated, and if reasonable rapidity was to be obtained only the last alternative was permissible. Acceleration of corrosion was, indeed, imperative in durability tests and the " practical " test thereby became impracticable in all but a few special cases (for example, bottles intended to contain solutions of alkaloids). It was therefore necessary to consider whether some simple test could be generally applied to all classes of glassware, the degree of severity of the test being in each case selected to correspond with the degree of resistance of the glass.

The value of resistance to corrosion by water as a criterion of durability had been questioned by certain speakers, apparently on the grounds that glass vessels were used to contain aqueous solutions and non-aqueous fluids much more frequently than water alone. Attack by most corrodents, however, was discontinuous, whereas that of water was unceasing, in virtue of atmospheric humidity. Failures from this cause were especially probable under tropical and semi-tropical conditions. Inability to withstand water-tests of reasonable severity was incompatible with general durability, and the fundamental importance of this criterion was therefore urged.

The proposal to distinguish three main types of glasses, from the point of view of durability, and to formulate conditions of test appropriate to each type had been adversely criticised and the adoption of a single standard test advocated. The attractiveness of the latter suggestion was illusory, for, since it was not disputed that glasses could be broadly grouped according to durability, it would be clear that a single method of test could not be appropriate to more than a few glasses, being much too exacting for some and insufficiently severe for the remainder. The employment of one temperature and one duration of test had been responsible in the past for much of the difficulty of interpreting results obtained in autoclave tests, particularly when series of experimental melts were in question, and faulty selection of testing conditions was the most general cause of anomalies.

It was recognised that a single test could not be expected to yield very precise information on the durability of glasses, and in this connection it was interesting to note that Mr. Withey also had suggested a series of tests at gradually increasing pressure.

Mr. Stott had mentioned a practical point of some importance. Standard practice in the author's laboratory was to leave the valves of the autoclave open until steam was blown off freely. This would probably fail wholly to remove, but would greatly reduce, the possibility of discrepancy between temperature and pressure. Certain anomalous results, already reported * were due mainly to the shortness of the thermometer tubulus in the head of the autoclave, apparently a general fault in construction.

The use of crushed glass, advocated by several speakers, would be found to be more fully discussed in the printed paper than had been possible when the paper was read.

It was not possible to agree that any autoclave test was necessarily much too drastic for certain qualities of glass, notably such as are employed in lamp-working. It could not be denied that much of the glass so used at present would fail in tests conducted even below the boiling point of water, but since glasses of good lamp-working properties were available which would withstand autoclave tests for an hour or more at 4, 6, and even 8 atmospheres, it was obvious that ease of production was perpetuating the employment of a considerable amount of material which, judged by durability alone, should not now be tolerated.

The discussion, in his view, had confirmed the claims of the autoclave test to be considered with a view to adoption as a standard. Such a test offered important practical advantages, and the results were at least as free from ambiguity as those given by the various other

* Baillie and Wilson, *loc. cit.*, p. 46T.

methods of test commonly employed. Perfection could not be attained in any single durability test, but the autoclave test appeared to be open to less vital objections than the others. It could not be overlooked that it was difficult to discriminate among durability tests, because an absolute measure of their efficiency could not be obtained, and it was frequently difficult to decide whether objections were really valid. There did, however, appear to be ample evidence in favour of the general utility of autoclave tests, and it appeared justifiable to suggest that, given graded test conditions, they would prove acceptable as standard methods of determining the durability of commercial glassware.

Prof. W. E. S. Turner (*communicated*) said in regard to the general question of the method to be adopted in testing the durability of glass, Mr. Baillie had launched a formidable attack on the use of glass powder. He (Prof. Turner) rather thought it was easy for the enthusiastic advocate of any one method to exaggerate the faults of other methods, but arm-chair criticism should not be final. He himself had for a long time fought shy of the use of glass powder, but repeated experiment during the last eighteen months in his Department had shown that some of its defects could be obviated and that some of the criticisms of it had little weight in practice. It was by no means a perfect method, but he had come to set considerable value on it. At some future time he might have to abandon his present rather favourable opinion of it, but there was no indication of this necessity yet.

He would like to remind others that despite the criticism which it was possible to make of Peddle for using glass powder, the results of that investigator for different glasses fell on smooth curves, whilst he had also demonstrated that the corrosion tests with powder gave the same classification of the durability of optical glasses as that obtained by the iodoeosin test, and by the ultimate tests of exposure to the atmosphere. It was difficult to imagine that Peddle's results could have been so concordant if all the objections to the powder method were valid.

From the discussion that had taken place, it seemed to him (Prof. Turner) that there was danger of confusion of thought in regard to the corrosion test. Those engaged in manufacturing operations desired, naturally, to test their finished products and appeared to take exception to testing glass, say, in the form of powder. He would like to point out, however, that there were two problems involved in durability questions, first the durability of the glass as glass, that is, as related to its composition, and, secondly, the durability as influenced by the physical condition of the surface, that is, as effected by contact with moulds, polishing media, etc. The only property which it was possible for all workers to test in the hope of obtaining comparable results was the durability of the glass as glass. In this connection it seemed to him that the use of glass powder had much in its favour, as a sample in average condition was thereby obtained, eliminating any dominating influences due to surface (mould effects, pouring lines, cords, etc.). It was a test of the durability of glass as glass that he himself was seeking for the purpose of scientific work, and whether it was the powder test or some other did not matter if, in the general opinion, the test fulfilled as fully as possible the scientific conditions. He felt sure, also, that the manufacturer must first satisfy himself that his glass complied with some standard to be set up on the basis of an agreed scientific test before he attempted to produce containers from it. The tests on the containers themselves might be desirable in addition, but such tests would yield different results according to the mode of operation in producing the article, and could not form the basis of a standard scientific test. He was inclined to consider that if manufacturers would ensure that their glass, as glass, was really durable, they need have but little fear of the surface effects referred to.

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ABSTRACTS AND REVIEWS

NOTE.

1. The abstracts of British Patents are taken from the official abstracts in "Illustrated Official Journal (Patents)."
2. The fact that an abstract is given of a U.S.A. Patent Specification does not necessarily imply that there is no corresponding British Patent Specification.

I.—Glass-making Materials.

1. Washing Sand, etc. H. Crowther, N. H. Crowther, and C. G. Crowther, Tunbridge Wells (Brit. Pat., No. **165257**, April 12th, 1920).—In apparatus for washing sand or other granular material of the kind in which the sand, etc., and water are passed in opposite directions through a tapered or conical rotary drum, the drum, *a*, is provided at the larger end with an enlargement, *b*, from which the washed sand is discharged to a fixed shoot, *l*, by buckets, *c*, of curved form in cross-section, spaced at their outer ends from the end, *e*, of the drum, and inclined as shown. The sand is fed to the drum from a hopper, *h*, and conveyer, *j*, and water from a pipe, *m*, and the interior of the drum is fitted with a helical conveying-blade, *k*. H. G. C.

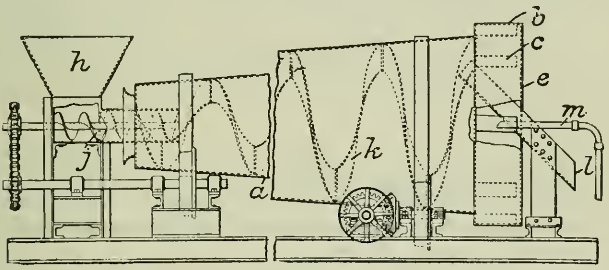

Fig. 1.

2. Potash in 1920. M. R. Nourse (*Mineral Resources of the United States*, 1920, Part II, 97).—During 1920, in U.S.A., about 83 per cent. of the total potash was produced in plants operating primarily on brines, alunite, silicate rocks, and wood ashes. The material was marketed in several forms, but chiefly as crude mixed salts comprising the output from the Nebraska lakes, sugar refineries, and molasses distilleries. The high grade chloride, obtained from brines and kelp; the low grade chloride from brine and silica rocks; and sulphate of potash, refined from cement dust, and alunite, constituted the remainder of the output.

Experiments were being conducted to discover a satisfactory and economical method for the separation of the potassium and sodium salts in the material obtained from the various lakes. In the table below, No. 1 states the composition of the advertised product from a Nebraska plant, and No. 2, a typical sample. The figures representing calculated salts were obtained by calculating all the SO_3 to K_2SO_4, the excess K_2O to K_2CO_3, all the Cl to NaCl, and assuming the remainder of the 100 per cent. to be Na_2CO_3.

Composition of Commercial Potash from Nebraska Lakes.

Reported analyses.

	1	2
K_2O	28·49	22·37
Na_2O	32·11	33·87
CO_2	21·91	22·88
SO_3	14·53	16·39
Cl	2·85	4·20
Loss on ignition...	—	1·02
Insoluble	0·11	0·20
	100·00	100·93

Calculated salts.

	1	2
K_2SO_4	31·60	35·64
K_2CO_3	16·72	4·60
Na_2CO_3	46·87	51·62
NaCl	4·70	6·92
Loss on ignition...	—	1·02
Insoluble	0·11	0·20
	100·00	100·00

The greatest output of potash was in Utah, where the brine used was similar in composition to the artificial brines of the German potash works. Solar evaporation of this brine produced crude salts of potassium, sodium, and magnesium. These salts were boiled with hot brine, and, on cooling, yielded high grade potassium chloride.

In California, efforts were being made to recover borax as well as potash from the natural brines.

In connection with the extraction of potash from alunite, tests showed that extraction was possible of 80 per cent. of the potash in ores running 5 and 8 per cent. V. D.

3. Bureau of Standards' Recommended Specification for Limestone, Quicklime and Hydrated Lime for Use in the Manufacture of Glass (*Glass Industry*, 1922, **3**, 54).—Quicklime should not contain more than 3 per cent. of carbon dioxide; hydrated lime not more than 5 per cent., and should contain sufficient water to meet the chemical requirements of the calcium oxide.

Three grades of each of the above materials were arranged, depending on the character of glass to be made. The limits of composition specified are given in Table I.

TABLE I.

Composition of Non-volatile Portion of Limestone, Quicklime, or Hydrated Lime.

	Class 1.		Class 2.		Class 3.	
Ingredients.	Max.	Min.	Max.	Min.	Max.	Min.
CaO+MgO	—	96	—	91	—	83
Ferric oxide	0·2	—	0·4	—	0·8	—
Sulphuric and Phosphoric anhydrides	1·0	—	1·0	—	1·0	—
Silica	4·0	—	9·0	—	17·0	—
Alumina	3·0	—	5·0	—	5·0	—

The calcium oxide content must not vary more than 2 per cent. either way from the contract figure agreed on. An approximate figure for the alumina should also be given in the contract, and should not vary more than 1 per cent. All samples should be such that the whole should pass a No. 16 sieve opening (1·19 mm. wire diam. 0·54 mm.). Each consignment should be distinctly marked, a notice of rejection be given to the consignor within ten days after receipt.

Samples selected for testing limestone or quicklime are to be taken from top to bottom of the bulk, one shovelful for each three tons of material, but not less than ten shovelsful in all taken from different parts. The total sample should be not less than 100 lb., and after "quartering," the sample sent to the laboratory to be 15 lb. In the case of packages of hydrated lime, 3 per cent. of the packages must be sampled, and taken from top to centre. After mixing and quartering, a 2 lb. sample should be sent to the laboratory. Care should be taken to exclude air from samples of quicklime or hydrated lime.

A brief summary of the analytical methods was given. V. D.

II.—Glass: Manufacture and Properties.

4. Technique of Ancient Glass Work. A. Kloster (*Sprechsaal*, 1921, **54**, 507).—The Egyptians were stated to have had skill in the fashioning of small glass flasks as far back as the second thousand B.C. These vessels were made by dipping a sand nodule into the glass, and withdrawing it, when the exterior was given the desired shape. The sand was then removed in the best way possible. All such glasses showed the roughened inner surface due to contact with the sand. Larger vessels could not be so made, and must have been carefully cut out of the solid. The Egyptians were very clever at this work and could cut, engrave, and polish. From the very regular profile of existing specimens and the presence of obvious tool-marks round the circumference of vases, forming a series of parallel circles, the lathe must have been known and employed by these craftsmen. Thus a vase was turned in two portions, the top being fastened to the bottom by a circular metal band and the handles by bronze attachments. Photographs were shown illustrating the fact that certain of the glasses had been cut in a lathe. M. P.

5. The Manufacture of Constructional Glass in the United States. E. W. Tillotson (*J. Soc. Chem. Ind.*, 1921, **40**, 155 T).—An account of present-day methods in the U.S.A. for producing all kinds of sheet glass—window, plate, wired, and heat-resisting. This section of the industry now had an output second only in importance to bottle manufacture; its remarkable development was due to the perfection of mechanical processes such as those of Lubbers and Colburn, rather than to advancement in chemical composition. A typical batch for window glass was: sand 1000, soda-ash 250, salt-cake 75, limestone 350, yielding a glass of percentage composition SiO_2 73, CaO 14, Na_2O 13; whilst for plate glass the batch was: sand 1000, soda-ash 310, salt-cake 65, limestone 320, the glass being composed of SiO_2 72, CaO 13, Na_2O 15. Casting-tables for plate glass varied in size, but the average would be 24 ft. × 14 ft., giving a sheet of 300 sq. ft. and requiring a pot of 2000 lb. capacity to melt the necessary glass. Recent improvements in plate glass grinding consisted in devices whereby the grinding sand from the tables was collected, graded, and returned to the tables.

Window-glass melting tank furnaces were now of large size, one recently erected having a content of 2000 tons and a daily melting capacity of 400 tons.

Methods used to produce wired glass and heat-resisting glass were referred to. F. W. H.

6. The Mechanical Drawing of Sheet Glass by the Libbey-Owens Process ("LE VERRE," 1921, **1**, 177).—In this process, the founded metal passes from the tank, 1, into a cooling-off tank, 2, in the middle of which is a damper, 8, regulating the heat supply, and thence to the actual drawing tank, 3. In the roof of the section 7 is an opening covered by a sliding brick to enable the temperature of the cooling furnace to be more readily controlled. In the side walls are archways, 12, giving access to the tank when necessary, but normally bricked up. The forward end of the cooling chamber is closed in by a block, 15, through which runs a water channel. The drawing tank is supported on pillars forming part of a heating chamber, 16, through passages in which pass burning gases to an exit flue, 17, which is also placed in communication with the space over the drawing tank by a brick, 18, 19. Burners, 20, heat the space above the drawing tank. At the end of the drawing tank nearer the main tank is a brick, 21, forming a curtain and supported by the brick, 22. The machinery for drawing the glass is housed in the space, 30, over the end of the drawing tank, in line with the annealing chamber, 32′, of which 33 and 34 are the roof and side respectively. The chamber, 30, is partly closed by a bend, 35, almost over the end of the drawing tank. The roof, 32, covers both the drawing chamber and the reheating chamber, 37, below which is the space from which the glass is drawn. The bottom of 37 is formed by a transverse member, 38, covered by a brick, 39, and by the block, 40. Heat is furnished by a port, 41, in the chamber, 42, which is separated from 37 by a perforated partition, 43. The bottom of 42 is formed of a horizontal block, 44, below which is another heating chamber, 45, with a perforated wall, 46, and a bottom block, 47. The drawing machinery consists of two endless belts, the lower, 50, forming an endless table propelled by the wheels, 51, mounted on transverse arbours, 52, 53, and the upper one, 60, being similarly propelled by 59 on 57 and 58. In addition, the upper belt, 60, is furnished with "caterpillar" feet (not shown) which, engaging on the glass surface, provide the necessary tractive force. To ensure that the glass sheet is not deformed by the feet, a plane slipway, 54, supports the lower endless belt where it carries the sheet and the sheet lies on this portion of the lower belt before the feet of the upper one engage on its surface. 65 and 66 are hollow bending rolls of the same diameter with a smaller supporting roller, 67, nearer the table. All these can be air- or water-cooled. Below 65 is a hollow chamber, 68, carrying a water channel, 69, and 70 is an air pipe with jets to cool that portion of 65 just about to come in contact with the glass, 11.

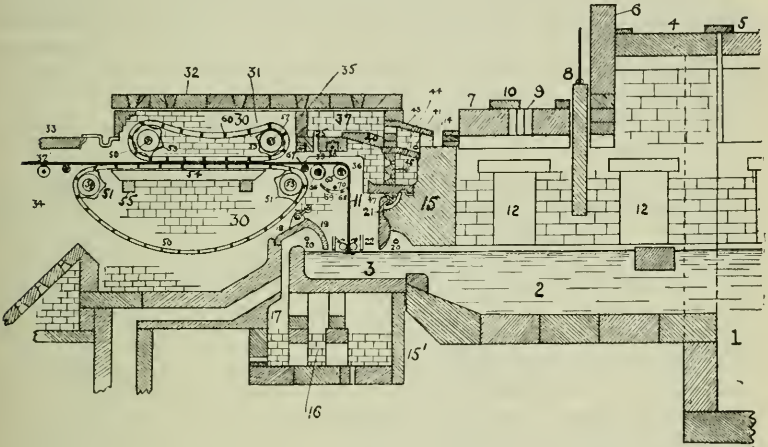

FIG. 2.

At the beginning of the drawing process a "blank" is placed on the table and the normal movement of the drawing machinery is reversed, thus feeding the blank over the bending roller, 65, down into the molten metal. When the metal has adhered to the blank, the machine is run normally, slowly drawing up the glass over the roller, 65, on to the table, when the blank is detached and the sheet glass follows the normal course. Water-cooled corrugated rollers are disposed on each side of the sheet and it has been found that better results as regards flatness of the sheet and freedom from damage by the bending rolls and drawing machinery are obtained if these rolls are run at a peripheral speed somewhat less than the speed of the glass over the drawing table. The optimum reduction is 10—20 per cent. By setting the corrugated rollers a slightly greater distance apart than the main thickness of the glass, a small thickening or cushion is left along the sides. The roller surfaces are adequately cooled to minimise damage to the surface of the sheet. To prevent damage to the sheet in passing over the roller, 65, due to too rapid cooling, jets of burning gas from 48 play on the surface of the sheet at that point. In proportion as the sheet is bent from the vertical to the horizontal plane, its temperature is lowered and there is a danger of its being too chilled and passing on to the drawing machinery with undulations in its surface, and therefore it is again heated, so that it falls flat on the table, 50, some distance before the feet of 60 engage on it. This heating is effected by a port, 125, in 37, the flame "licking" the surface of the glass after its passage over the bending roller.

The thickening formed by the corrugated rollers is flattened more or less, leaving a thickening in relief on the top edges of the sheet, and this swelling is engaged by the caterpillar feet, thus protecting the sheet as a whole from damage.

The machine is claimed to be capable of drawing a sheet 5 feet wide at a speed of 24 to 100 inches per minute, the speed depending on the thickness. Thus glass $\frac{1}{24}$ inch in thickness can be drawn at 97 inches per minute, while $\frac{1}{4}$ inch thick glass can only be drawn at 24 inches per minute.

Attempts are being made to use the machine for the drawing of wire glass. M. P.

7. Note on the Dissociation of Ferric Oxide Dissolved in Glass and its Relation to the Colour of Iron-bearing Glasses. J. C. Hostetter and H. S. Roberts (*J. Amer. Cer. Soc.*, 1921, **4**, 927).—The authors showed that above a temperature of 1300° iron sesquioxide (Fe_2O_3) was dissociated appreciably with the evolution of oxygen and the formation of corresponding quantities of ferrous oxide (FeO). The oxygen lost at high temperature was reabsorbed at lower temperatures if the charge was cooled slowly, thus indicating that the action was reversible. The formation of ferrous oxide by dissociation was to be carefully distinguished from the reduction of ferric oxide by such constituents of furnace gases as carbon monoxide and hydrocarbons. The formation of ferrous oxide by dissociation in the first case took place under what were ordinarily considered to be oxidising conditions.

The same reaction was found to take place in glasses, that is, the ferric oxide dissolved in glass lost oxygen at high temperatures even under oxidising conditions. The following percentages of iron as ferrous oxide, based on the total iron present, illustrated the extent of this dissociation in glasses. Diopside glass ($CaSiO_3,MgSiO_3$) at 1400° showed 20 per cent.; at 1500°, 30 per cent.; at 1600°, 45 per cent. A glass of the composition $0{\cdot}6K_2O,0{\cdot}4CaO,2SiO_2$ showed at 1310°, 5·8 per cent.; at 1555°, 10·1 per cent. Another containing $0{\cdot}3K_2O,0{\cdot}3Na_2O,0{\cdot}4CaO,2SiO_2$ showed at 1020° 4·1 per cent. of the total iron content as ferrous oxide. In the two latter glasses a dissociation of 10 per cent. produced a bright green colour; the glass with 4·1 per cent. dissociation was yellow. The intensity of the colour due to iron was closely related to the composition of the glass, but data on this point were not sufficiently complete to warrant generalisations. F. W. H.

8. Copper Ruby Glass. H. Kühl (*Sprechsaal*, 1921, **54**, 383).—One of the oldest and most interesting works on copper ruby glass was that by P. Ebell (1870), who, although writing before colloidal chemistry was understood, drew sound conclusions as to the cause of the colour. The preparation of copper ruby, however, was, on the whole, not so well understood as that of gold ruby. As the two were of similar nature, the amount of the metals used to produce the same intensity should not differ widely, but whereas, according to Müller, 1 part of gold per 50,000 parts of glass gave a bright red colour, the amount of copper needed was uncertain, and many views were incorrect. Randau, for instance, had stated that the weight of copper should be 2 per cent. of that of the batch. By the use of methods similar to those for preparing gold ruby, the author had obtained the colour by the use of 0·02 per cent. of copper. Haller prepared a beautiful ruby from the batch: sand 100, potash 30, soda-ash 2·5, limespar 12, copper sulphide 0·02, sodium sulphide 0·026, borax 0·024. A ruby batch patented in 1882 had the composition: fine sand 2000, red lead 400, potash 600, lime 100, calcium phosphate 20, potassium bitartrate 20, cuprous oxide 9, stannic oxide 13. The copper here was only 0·40 per cent. of the weight of sand used. Randau used a much higher proportion in the batch: sand 100, soda 18, stannic oxide 20, cupric oxide 15, iron oxide 10. In the manufacture of copper ruby, the batch should be one melting at not too high a temperature and allowing normal working, whilst the copper salt should be easily reducible and very finely divided. The melt should be of a reducing character. In many failures the fault had been due to the use of a too strongly basic batch resulting in the production of crystals of cuprous oxide, in which case a liver-brown colour was obtained with incident light. A. C.

9. The Application of "Red Mud" (in Glass Making). O. Lecher (*Ker. Rundschau*, 1921, **29**, 530).—"Red mud" was obtained in large amounts in the preparation of purified aluminium hydroxide from bauxite. It contained all the iron oxide and lime and most of the silica from the original bauxite. In large works, much of the mud had not found commercial application (although some had been used for such purposes as the purification of lighting gas), and consequently the material was not valued highly, and was cheap. Two dry commercial samples of the product had the following percentage compositions, respectively: Moisture 7·8 and 8·1; loss on ignition 12·3 and 14·9; silica 11·0 and 12·8; ferric oxide 50·9 and 48·2; lime 8·2 and 9·9; magnesia trace (first sample); titanium oxide 0·23 (first sample).

Two small trial melts were made, using the following batch: sand 75·5 gm.; powdered marble 21 gm.; soda-ash 21·5 gm. (all practically iron-free), the first batch containing 0·7 gm. of the red colouring matter, in which case a beautiful bright green glass was obtained, the second 1·4 gm. of the colour, when a pure dark green glass resulted. A series of melts in which the substance was used in conjunction with manganese dioxide gave a set of clear and transparent greens and ambers. A. C.

10. The Devitrification of Glass. A. F. O. Germann (*Amer. J. Sci.*, 1921, **1**, [**201**], 279).—The peculiar behaviour of many old glasses on heating was found by the author to be due to a surface change, and the glass could be made workable again by washing the surface with dilute hydrofluoric acid. In this way, a thin surface film was dissolved from the glass. The author attributed the surface change to the absorption of moisture, but observation showed that the change might be somewhat complex, and that carbon dioxide might take part in the action. V. D.

11. Some Relations of Composition to Solubility of Enamels in Acids. H. F. STALEY (*J. Amer. Cer. Soc.*, 1921, 4, 703).—The literature on acid-resisting enamels and glasses was reviewed. J. B. Shaw (*Bur. Standards*, Tech. Paper, No. 165, 81), in investigating white enamels for sheet steel, drew the conclusions that fluorine, added as fluorspar or cryolite, rendered them subject to easy attack and destruction by ordinary lemon juice. Boric oxide in easily fusible enamels rendered them easily destroyed by weak acids such as lemon juice, but in refractory enamels could be used in small amounts without danger. This conclusion was substantiated by the Pyrex and other chemical glasses now on the market. Hovestadt stated that in lime–soda glasses with more than 70 per cent. of silica the attack by acids was less than by pure water, and diminished with increased concentration of the acid. However, with low silica glasses such as high lead glasses and complex borosilicates, water had little effect, but acids, particularly hydrochloric acid, readily attacked them. Further, whilst calcium oxide gave glasses high resistance to the attack of water, and sodium oxide low resistance, calcium silicates were more readily attacked than sodium silicates by acids.

Since many contradictory results had been obtained, the author determined to investigate the general effects of various oxides and minerals on the solubilities of their products. Starting with an enamel having, in round numbers, the following composition, namely, SiO_2, 68 per cent., B_2O_3, 7 per cent., Na_2O, 19 per cent., CaO, 6 per cent., about seventy enamels were compounded. The enamels were subjected to the action of 20 per cent. hydrochloric acid. When substituted one for another, in each case in equal percentage amounts, various oxides and minerals increased resistance to acid attack in the following order of effectiveness: Al_2O_3, cryolite, Na_2O, PbO, BaO, Li_2O, MgO, CaF_2, ZnO, SiO, CaO, B_2O_3. The first five mentioned were specially effective, but the remainder were undesirable materials from the point of view of acid resistance. The presence of Na_2O in the group of favourable oxide substitutes and of ZnO and CaO among the unfavourable ones was contrary to current assumptions in regard to resistance of glass to chemical action. Zinc oxide was a common constituent of chemical glasses, but these contained such high percentages of silica that the qualitative differences in effect of the basic oxides were negligible. Zirconia and titanium oxide (rutile), when substituted for small amounts of silica, increased the resistance of various enamels to attack by acid, zirconia being most effective in this respect. The favourable action of zirconia was offset by a tendency to produce excessive chipping. Rutile gave less chipping than either zirconia or silica, and greater acid resistance than silica.

F. W. H.

12. Tests for Laboratory Resistance Glassware. (*J. Inst. Chem.*, 1920, **3**, 202).—This scheme was prepared by the Glass Research Committee of the Institute of Chemistry, and generally approved by the National Physical Laboratory. The limits set out were considered as the minimum for resistant chemical glassware. Other, and specific, tests were necessary for testing glass for special service, as, for instance, toxicological work. Thus, glasses containing arsenic and antimony, although quite satisfactory for use with acids, were unsuitable for use with sodium hydroxide, as even dilute alkali dissolves a little arsenic and antimony.

The general procedure was as follows :—

I. *Preliminary Treatment.*—Distilled water is heated to boiling point in flask or beaker, rinsed, and poured out, rinsed again with a little 5 per cent. acetic acid with a few pieces of filter-paper added, and finally cleaned with hot distilled water.

II. *Treatment in Autoclave.*—A flask or beaker is filled with distilled water, and placed in the autoclave containing water, the vessel being supported *above the surface of the water* on a pure silver plate surrounded with a cylinder of pure silver foil, the cylinder being covered with another silver plate. The heating is conducted for three hours at the registered pressure of four atmospheres. Half the water from the flask or beaker is evaporated in a platinum dish, the residue heated for an hour at 120°, gently ignited (not above 650°) for not more than three minutes, and weighed. The interior surface of the vessel is calculated and the residue expressed in mg. per sq. dcm. The alkalinity of the remaining half of the liquid is determined by titration with $N/10$- or $N/100$-sulphuric acid, using methyl-orange as indicator. The result is expressed as c.c. $N/100$-acid per sq. dcm. The appearance of the vessel is noted when dry. *Residue not to exceed* 4 *mg. per sq. dcm. Alkalinity not to exceed* 5 *c.c.* $N/100$-H_2SO_4 *per sq. dcm. Glass must not flake or peel.* Vitreous silica could replace the silver plates, and copper could be used instead of silver.

III. *Treatment with Reagents.*—(*a*) One hundred c.c. of conc. HCl (sp. gr. 1·15) are placed in another flask treated as in I, the mouth is covered with platinum foil, and heated in an air-bath, so that the acid boils gently for half an hour. The bath should give 3 cm. clearance at the greatest horizontal diameter of flask, and a thermometer should be fixed with bulb level with centre of flask, and temperature should be 140°±5°. The acid is evaporated to dryness in the vessel in the bath, and the process repeated twice. The residue is acidified, washed out into a platinum dish, and evaporated to dryness. A weighed quantity (about 0·1 gm.) of ammonium carbonate (powdered) is sprinkled over the residue and ignited, the process being repeated twice, then the residue weighed. The weight of residue left on evaporation of 300 c.c. of the acid treated with ammonium carbonate as above is deducted. The appearance of the vessel is noted when dry, and the whole area of the inner surface of the flask is calculated, and the result expressed as mg. per sq. dcm. The whole treatment should be repeated, using the same vessel. Residue from first treatment must not exceed 2 mg. per sq. dcm. Residue from second treatment must not exceed 1 mg. per sq. dcm.

(*b*) Test is made for silica by fusing the combined residues with Na_2CO_3 and K_2CO_3, extracting with water, and evaporating to dryness on a water-bath with HCl. After two more evaporations with HCl the residue is extracted with dilute acid and tested for zinc.

(*c*) After treatment with HCl, 50 c.c. of 2*N*-ammonium chloride solution is poured in, with 50 c.c. of ammonia (1 part of 0·88 ammonia and 3 parts of water) and the solution boiled for half an hour on a hot plate covered with asbestos, the mouth of the flask being covered with platinum foil. The solution is evaporated to dryness in platinum, dried at 105°, ignited, and the residue weighed. The blank on the solutions is deducted. The result is expressed as mg. per sq. dcm., and the appearance of the flask noted. Residue must not exceed 1·5 mg. per sq. dcm.

(*d*) Sodium hydroxide treatment, for distinguishing glass unsuitable for work where contamination of contents must be avoided, consists in boiling 100 c.c. of 2*N*-sodium hydroxide solution in a weighed flask or beaker counterpoised against a similar vessel for four hours on a hot plate. A pure silver test-tube, through which runs cold water, is used as a condenser in the mouth of the flasks, whilst a silver round-bottomed flask is used with beakers. The vessel is washed out, dried, re-weighed, and inspected. The solution and deposit are tested for zinc and lead, and the whole process repeated.

IV. *Heat Tests : Alternative Methods.*—(*a*) Flask or beaker heated in air oven at 120° for half an hour is then quickly immersed in cold water (14—15°). The bottom of the oven could be removed, and the flask dropped into the water below. A thermometer inside the flask should register 120° for at least ten minutes before chilling takes place.

(*b*) The vessel is three-quarters filled with paraffin wax, heated in an air-bath at about 155°, the wax stirred, the temperature read, and the flask removed from the bath. When the temperature falls to 150°, the flask is plunged into water at 15°. The test is repeated at increasing temperatures rising by 25° until the vessel breaks. Good glass withstands more than 200°.

(*c*) A solution of calcium chloride (sp. gr. 1·33 at 15·5°) is boiled for five minutes in another vessel, then plunged into water at 0°.

(*d*) A flask full of water at 0° is plunged into boiling water.

Good quality glass should withstand tests (*a*), (*c*), and (*d*).

V. *Tests for Arsenic and Antimony.*—Testing for arsenic, 10 gr. of the glass in pieces of ½ in. to 1 in. square, are placed in a round-bottomed flask of 400 c.c. capacity, with 100 c.c. arsenic-free HCl (sp. gr. 1·15), 100 c.c. solution of ferric chloride in arsenic-free HCl, and 2 gm. of arsenic-free ferrous sulphate crystals. The mixture is distilled, 75 c.c. to 100 c.c. distillate being collected, and tested for arsenic. If more than 0·5 mg. of arsenic is found, then it is precipitated by H_2S, and the sulphide weighed on a Gooch's crucible, or titration with iodine solution after neutralisation of the acid with sodium bicarbonate. When very minute quantities of arsenic are present, the distillate is treated with zinc, (*Brit. Pharmacopœia*, 1914), producing a yellow stain with mercuric chloride, an aliquot part of distillate being used. Alternatively, evaporation of the acid with Na_2CO_3 and bromine or nitric acid could be employed, the residue being reduced by potassium metabisulphite, and the arsenic estimated in an electrolytic apparatus, using standard mirrors for comparison. Rubber stoppers must not be used in this test and corks must be replaced periodically. Ground glass joints are preferable throughout the apparatus.

The ferric chloride solution is made by dissolving 400 gm. of the solid in a litre of HCl (sp. gr. 1·15) adding 20 gr. of $FeSO_4$ crystals, then distilling until free from arsenic, the original volume being restored by more HCl. Blanks on materials are allowed for.

In the case of some storage vessels, the test is carried out by allowing HCl to stand in the vessel for forty-eight hours and then testing for arsenic as described above.

Glassware to be used for analytical purposes should not yield arsenic when tested, and if any appreciable quantity be obtained, the glass should be rejected for ordinary laboratory use. If no arsenic be detected under test, yet, in prolonged use, some may be dissolved. Reduction and distillation of the arsenic chloride obtained from an HCl extract of a sodium carbonate fusion of finely powdered glass could be employed, but no need of this arose.

Although antimony-containing glasses had proved unexceptional in use, yet the presence of this element should be notified, and a satisfactory test could only be made by analysis, the glass being decomposed by HF and H_2SO_4.

VI. *Annealing.*—The vessels must not show marked or irregular strain when viewed under polarised light.

Convenient Dimensions of Vessels to be Tested.—*A*. Flasks: flat bottomed, spherical.

Height, 15·6 cm.; total volume, 365 c.c.; diam. of sphere, 8·8 cm.; height of neck, 7·2 cm.; Int. diam. of neck, 2·2 cm. Total int. surface = surface of sphere + surface of neck = 292·7 sq. cm. = 3 sq. dcm. approx.

B. Beakers: cylindrical, slightly tapering.

Height, 10·8 cm.; volume, 330 c.c.; diam.: base 6 cm., top 6·7 cm. Int. surface = curved surface of cylinder + area of base = 245·3 sq. cm. = 2·5 sq. dcm. approx. V. D.

13. Specifications and Standard Methods for Testing Lime-Flint Glass. A. E. Williams (*Glass Industry*, 1922, **3**, 47).—A special study was made of glass tumblers, and covered the following points: (1) Type of glass, whether lead or lime glass. (2) Suitability of tank furnace glass or pot furnace glass. (3)

Whether a hand-finished article was essential. (4) Whether both hand-made and machine-made tumblers were admissible.

The specification was designed to test the following qualities: (1) Ability to preserve a good appearance in service. (2) Strength compatible with style. (3) Annealing sufficient to provide against light blows and reasonably sudden changes in temperature. (4) Dimensions, and limits. From the experimental work carried out, a specification for lime-flint glass tumblers was drawn up as follows:—

Measurements.—Capacity 10 fl. oz.; wt. 12 av. oz.; height, $4\frac{1}{4}$ in., outside diam., top, $2\frac{7}{8}$ in., bottom, $2\frac{3}{4}$ in.; thickness of bottom in centre, $\frac{5}{16}$ in., $\frac{1}{2}$ in. at the side. Foot smooth and level.

Manufacture.—Tank or pot glass admissible, either hand- or machine-made, and hand- or machine-fire-polished.

Quality.—Faint colour, or few scattered bubbles (not exceeding 0·05 in. diam.) admissible. Dull surface must be eliminated. Samples picked at random must be free from stones, cords, and fine cracks. They must withstand quenching test and boiling test.

Limits in Size and Weight.

	Minimum.		Maximum.	
Capacity	9·7 fl. oz.	287 c.c.	10·3 fl. oz.	305 c.c.
Weight	11·3 av. oz.	320 gr.	12·7 av oz.	360 gr.
Height	4·15 in.	105 mm.	4·35 in.	110 mm.
Outside diam., top	2·80 in.	71 mm.	2·95 in.	75 mm.
,, ,, bottom	2·70 in.	69 mm.	2·85 in.	72 mm.
Thickness of bottom at side	0·40 in.	10 mm.	0·60 in.	15 mm.
,, ,, ,, ,, centre	0·25 in.	6 mm.	0·40 in.	10 mm.

The Shock Test employed to test tendency to spontaneous breakage consisted in pouring boiling water into the sample at room temperature until full. No cracking must occur on repetition of the test five times.

The boiling test necessitated the boiling for six hours of the sample in a closed vessel with a small steam vent. The sample must show no sign of corrosion, scumming, or cracking. The number of samples for tests must be taken from each barrel of a shipment, according to the total quantity, and 95 per cent. of the samples must pass the tests in order for the shipment to be acceptable.

Examination of tumblers for hotel use showed that, when struck by a hammer moving like a pendulum, their resistance to blows varied from 1·7 to 3·5 foot-pounds on the foot, and from 0·3 to 1·5 foot pounds on the side; that is, a 12 oz. tumbler would withstand a fall of from 2 ft. 3 in. to 4 ft. 7 in. on to a cement floor, landing on the foot.

The strength of tumblers showed a closer relation to composition than to any other factor. Improper composition of the glass resulted in high solubility, or even cracking on washing. All glasses tested were badly chipped after forty-eight hours' boiling, and many had fallen to pieces. Very few tumblers withstood transference from boiling water to ice water, and a temperature change from 70° to 0° caused breakage in all cases after three or four immersions. Transference from hot to cold caused fractures oftener than from cold to hot. V. D.

14. Tests of Beverage Bottles. A. W. Bitting (*Glass Container*, 1921—22, **1**, No. 4, 14).—Tests were carried out on one hundred and eighty lots of beverage bottles in order to determine what such testing might reveal in connection with a variety of shapes and sizes. The samples ranged from as small as 6 oz. capacity and $2\frac{1}{8}$ inches diameter to $\frac{1}{2}$-gallon bottles of $4\frac{1}{4}$ inches diameter. Plain bottles were compared with decorated ones, and with those made as colourless, light green, dark green, emerald, and amber colour.

The bottles were classified according to diameter, then subdivided according to shape, and, to some extent, according to capacity.

The vertical pressure necessary to fracture a bottle was measured by placing the sample between two sheets of copper, then subjecting it to a progressively increasing pressure in a testing machine. The lateral maximum pressure withstood was obtained by placing the bottle on its side between two 3-inch strips of hard maple, reaching to within 1 inch of the bottom. The gradual increase of pressure had to be kept quite uniform, and readings taken at once, in order to get comparative results; for a bottle might have withstood a pressure of 8000 lb. yet not survive a pressure of 7500 lb. for fifteen to thirty minutes. A few bottles reached the limit of the machine, namely, 12,500 lb., but no one set attained such an average. The hydrostatic pressure was obtained by forcing water into the bottles through a cover clamped to the neck.

The impact test was carried out by means of a hammer swinging as a pendulum through a 5 feet radius. The bottom of the bottle was placed in position, and a piece of hard wood placed against the mouth received the blow. Hammers weighing 5 lb., 10 lb., 20 lb., and 50 lb. were used in succession, but few bottles withstood the 300 foot-pounds smash. The maximum drop of the hammer was 6 feet.

Resistance to sudden change in temperature was determined by first chilling the samples in water, then transferring them to another tank 100° F. higher in temperature. Nearly every bottle passed this test.

Uniformity of thickness of the glass was tested by measurement of extremes along any line of fracture, excluding the bottom, and any extra thickness within half an inch of the bottom. Tables of results were given, and from them it was evident that at least beverage bottles were not fragile. V. D.

15. Transformation of Aluminium Silicates by Salt Solutions at Temperatures up to 200°. Hans Schneiderhöhn *Jahrb. Min.*, 1915, **40**, 163; from *J. Chem. Soc.*, 1921, **120**, Abs. ii, 114).—A study of the analytical results of several workers who investigated the products of the action of various salt solutions on many aluminium silicates, both natural and artificial, at temperatures up to 200°. It was shown that the action of such solutions on felspar, leucite, hauyn scapolite, seolite, sodalite on amorphous synthetic silicates and on kaolin was to give as initial transformation products silicates of the type $R''O, Al_2O_3, xSiO_2, yH_2O$, in which the molar ratio of the base $R''O$ to alumina was always unity. The continued action of alkali hydroxides or carbonates gave a final product containing $2SiO_2$. The water content depended on the base and the physical condition of the initial material.

A further type of compound, $Na_2O, Al_2O_3, 2SiO_2, yH_2O, 2NaX$, was obtainable from the above silicates by the action of very concentrated caustic soda or sodium carbonate solutions, X being any organic or inorganic acid radicle. In these the molar sum of the water and the added salt NaX always have a simple relation to the alumina.

Further secondary decomposition products were described and their close relation to the permutites, especially in the matter of susceptibility to basic exchange, was emphasised. M. P.

16. The Nature of the Electrical Conductivity of Glass. H. H. Poole (*Nature*, 1921, **107**, 584).—A study of the nature of the currents obtained in dielectrics such as glass when subjected to high electrical pressures.

A thin glass bulb and tube were filled, the day before the test, with a dilute neutral solution of calcium chloride containing a little phenolphthalein. This bulb was immersed in a small beaker containing tap water placed on an insulating stand. One electrode was placed in the tube, and the other in the beaker, one of them being connected to a source at a potential of — 8000 volts, with the aid of rectifying valves, the other being connected to earth through a sensitive galvanometer. A known current could thus be passed through the bulb in either direction.

A slight pink colour had developed in the calcium chloride solution while standing, previous to the test, due to the solution of alkali from the glass. The central electrode was first used as the anode, the glass of the bulb acting as cathode to the solution. The current rose from 8·5 to 13 micro-amps. in fifteen minutes. The solution in contact with the thinner parts of the bulb was of a deep pink colour. This pointed to the electrolysis of the solution, the glass conducting as a metal, and not purely electrolytically, for in the latter case the alkalinity of the solution would have been decreased or neutralised by the acid radicle ions sent into solution from the glass. When the current was reversed, with an initial value of 16 micro-amps., the solution in contact with the glass was almost colourless in six minutes. Had the current been of a purely electrolytic nature in the glass, the sodium ions entering the solution from the glass would have maintained the pink colour.

The conclusion drawn was that under such conditions, and at atmospheric temperature, the conduction current in glass was largely, if not wholly, of a non-electrolytic nature. V. D.

17. Double Refraction and Crystalline Structure of Silica Glass. Lord Rayleigh (*Proc. Roy. Soc.*, 1921, [*A*], **98**, 284).—The silica glass produced by the fusion of clear, crystalline quartz was found to have a doubly refracting structure which could not be accounted for as due to stress, and was therefore regarded as due to a crystalline structure. Ordinary glasses, on the other hand, generally showed no double refraction except that due to the existence of stress, resulting from bad annealing.

The double refraction shown by silica glass was found to be extremely weak, being of the order of one-sixtieth that of crystalline quartz. Observations made on a mass of fused silica which had not been drawn or blown showed that doubly refracting grains, oriented at random, and having dimensions of about $\frac{1}{2}$ mm., composed the structure. These grains survived a second melting of the silica, and it would appear that they corresponded with the grains of quartz used for the production of the glass. Elongation of the grained silica while soft resulted in crystalline fibres, or ribbons, giving "straight extinction" in the polariscope, and their length was along one axis of the ellipsoid of optical elasticity, but not always along the same axis. This flow of the grains rendered them similar to Lehmann's liquid crystals. When the silica was bent or twisted, the fibres or ribbons remained unbroken. Using silica which had not been repeatedly heated and worked, it was seen that bright crosses were shown in polarised light. These figures were much more brilliant than those of the crystalline structures described above, and although they were never found in rod, tube, or in built-up optical silica, they were most common in the material which had only been heated once. Examination showed that these crosses were centred in an inclusion in the glass, and they could be closely imitated by driving a conical metal plug into a piece of sheet celluloid. The crosses therefore were obviously due to stress.

In the case of built-up optical silica a peculiar strain structure was observed, with the crystalline grain effect superposed. A polished disc was examined, heated, quenched in water, and then found to be covered by a network of fine superficial cracks. These were ground out, the surface polished, and then examined. The grain structure had entirely disappeared, but on further heat treatment it gradually reappeared, fading again with further heating.

Prolonged heating resulted in devitrification of all kinds of silica glass, and this may be due, as generally supposed, to the formation of tridymite, giving much stronger double refraction than the structures described by the author. V. D.

18. The Dixon Strain Finder. E. E. Milner (*National Glass Budget*, 1921, **37**, No. 31, p. 14. *The Glass Industry*, 1922, **3**, 62).—In principle the Dixon strain finder is exactly the same as those already described by Wilson (this Journal, Trans., 1919, **3**, 256) and English (*ibid.*, 258), but the detail and construction are slightly different. The polarised light is produced by reflection and is analysed by a small Nicol prism.

Inside a metal lantern of parabolic section is fitted an electric lamp which throws a concentrated beam of light through an opal diffusion lens on to a highly polished metallic reflector. On reflection, the beam of light is partly polarised and travels in an approximately horizontal direction. The Nicol prism is mounted in an adjustable holder on a separate stand. In front of the reflector a shelf is provided on which articles may be placed for examination. S. E.

19. The Composition of Barium Glasses. R. J. MONTGOMERY (*J. Amer. Cer. Soc.*, 1921, **4**, 536).—The relation between the composition of barium glasses and the optical constants was discussed together with the general rules for proportioning batches. Compared with the lead glasses (see Abs. No. 6, this JOURNAL, 1921, **5**, 9), the compositions of barium glasses could not be so easily collated owing to the greater complexity of the batch. The zone covering the relation of optical properties to composition, which was narrow in the case of the lead glasses, was here much wider with a dispersion, as expressed by the ν value, ranging from 54 to 61 and a refractive index, for the D line, from 1·50 to 1·63.

In the paper on lead glasses referred to above, the compositions were discussed on the equivalent weight basis, but with barium glasses it was found that little or nothing was gained by employing the equivalent weight basis because of the complexity of the glasses. There were no simple relations between composition and optical properties, and the relations observed had to be expressed in more general terms. The composition was given in percentages by weight of the oxides present. The optical properties discussed were the refractive index for the D line, N_D, and the reciprocal dispersion defined by the equation $\nu = \frac{N_D - 1}{N_F - N_C}$.

The figures for the glasses discussed were given as in the table on page 19, and the results were further expressed diagrammatically.

Barium used in soda–lime glasses increased the index of refraction without lowering the dispersion value. The ν value decreased, however, with decrease of SiO_2 which the BaO displaced. The relation between the increase of refractive index and the barium content was practically a straight line as the barium oxide increased up to 40 or 42 per cent. Above 42 per cent. and up to 54 per cent., very little change in refractive index was noted, the line becoming almost horizontal.

Boric oxide, added to high barium glasses to prevent crystallisation on cooling, and silica were consistent in their effects on the optical properties except in one case. Boric oxide glass had a refractive index 1·463 and a dispersion 59·4, whilst silica glass had figures 1·4585 and 67·9, respectively. In a high barium glass silica lowered the index more than boric oxide. Addition of the latter often raised the refractive index in both barium and lead glasses when the index was about 1·60. Boric oxide tended to increase the ν value when the silica content was constant.

The proportions in the batches were dealt with. There was a decided drop in the silica content with increase of barium oxide content. The amount of alkali increased with the silica. Potassium

No.	SiO_2.	B_2O_3.	K_2O.	Na_2O.	BaO.	CaO.	ZnO.	As_2O_3.	Al_2O_3.	PbO.	N_D.	ν.
1	71·56	—	9·01	8·08	2·61	8·02	—	0·72	—	—	1·5160	60·0
2	68·50	3·50	5·00	12·00	9·70	—	1·00	0·20	—	—	1·5179	60·9
3	64·60	2·70	15·00	5·00	10·20	—	2·00	0·40	—	—	1·5179	60·2
4	67·00	3·50	5·00	12·00	10·60	—	1·50	0·40	—	—	1·5171	59·6
5	59·13	3·04	9·70	3·16	19·25	0·13	5·00	0·34	0·11	—	1·5409	59·6
6	49·57	4·51	8·49	1·01	26·06	—	10·03	0·34	—	—	1·5666	58·1
7	48·10	4·60	8·00	2·00	26·05	2·00	8·40	0·50	—	—	1·5755	57·2
8	48·10	4·50	7·50	1·00	28·30	—	10·10	0·40	—	—	1·5726	57·5
9	48·00	4·50	6·10	2·00	29·50	—	10·00	1·40	—	—	1·5754	57·5
10	48·45	3·65	7·55	0·95	32·63	—	6·46	0·32	—	—	1·5727	58·0
11	37·23	6·02	—	3·19	40·40	—	10·79	0·37	1·98	—	1·6167	54·0
12	37·30	6·00	—	3·20	40·50	—	10·80	—	2·00	—	1·6097	55·7
13	37·50	15·00	—	—	41·00	—	—	—	5·00	—	1·5899	60·8
14	34·50	10·10	—	—	42·00	—	7·80	0·50	5·00	—	1·6088	57·0
15	39·63	6·04	—	—	42·08	—	9·24	0·50	2·50	—	1·6054	56·5
16	36·28	5·57	3·20	—	43·62	0·21	10·73	0·39	—	—	1·6147	55·3
17	37·00	5·00	2·60	—	44·00	—	7·70	0·70	—	3·00	1·6242	53·5
18	39·60	5·00	—	—	44·00	2·00	7·70	0·40	—	3·00	1·5905	57·0
19	39·00	5·00	—	—	45·00	2·60	7·00	0·40	1·00	—	1·6145	56·3
20	37·80	5·69	3·50	—	45·04	—	7·56	0·40	—	—	1·6085	55·9
21	34·56	10·96	0·09	0·21	46·91	—	1·14	0·59	5·02	—	1·6091	58·8
22	37·00	5·00	2·60	—	47·00	—	7·70	0·70	—	—	1·6177	55·2
23	32·27	12·90	0·33	—	47·20	—	1·12	0·20	6·10	—	1·6139	58·5
24	38·29	5·76	2·84	—	47·60	—	5·11	0·41	—	—	1·6085	56·9
25	38·12	7·18	2·40	—	49·37	—	2·54	0·41	—	—	1·6062	57·3
26	36·58	11·60	0·10	0·22	49·66	—	1·21	0·62	—	—	1·5991	59·0
27	36·46	8·91	1·21	—	52·88	—	—	0·39	—	—	1·6091	58·4
28	36·51	8·93	1·22	—	52·96	—	—	0·39	—	—	1·6138	58·6

was the alkali almost invariably used because the sodium compounds gave more colour. The amount used depended on the flux required after the silica, barium oxide, and boric oxide contents were adjusted to give the required optical constants. It was not necessary to use alumina to control the optical properties, but it was almost invariably used, and the amount appeared to depend on the boric oxide content. Alumina was seldom used until the glass contained at least 5 per cent. of boric oxide and then it increased quite rapidly with addition of barium oxide, reaching a maximum at about 6 per cent. Zinc oxide might run as high as 11 per cent., but it had little effect on the optical properties. It was used largely to fill in when it was undesirable to increase any of the other constituents, and might be used to replace barium oxide to lower the refractive index or replace boric oxide to lower the ν value. F. W. H.

20. The Stability Relations of the Glass and Crystal Phases of Silica. R. WIETZEL (*Zeitsch. anorg. Chem.*, 1921, **116**, 71).—The heats of crystallisation and heats of solution in hydrofluoric acid of quartz, chalcedony, and cristobalite were determined, the following values being obtained :—

	Concn. of acid.	Heat of soln. per mol./cal.	Heat of crystalln. per mol./cal.
Quartz glass	35%	35·97 (mean)	—
Rock crystal	35%	33·65 ,,	2·2—2·35
Cristobalite (1600°)	35%	—	0·60
Cristobalite (1100°)	35%	—	0·54
Chalcedony	fuming	36·72 ,,	2·11—2·28

The mean specific heat between 0° and $t°$ in cals./gram gave the following values :—

		Cristobalite.			
$t°$.	Vitreous quartz.	1600°.	1100°.	Rock crystal (from Heraeus).	Chalcedony.
100°	0·1850	0·1896		0·1860	0·1965
200°	0·2006	0·2125		0·2031	0·2115
250°	0·2068	0·2241* 0·2355†	0·2268	0·2111	0·2170
400°	0·2229	0·2428	0·2367	0·2288	0·2325
575°	0·2366	0·2507	—	0·2480* 0·2527†	0·2510
600°	0·2385	0·2521	0·2482	0·2530	0·2523
800°	0·2506	0·2601	0·2570	0·2585	0·2590
1000°	0·2584	0·2656	0·2640	0·2630	0·2633
1200°	0·2621	0·2702	0·2682	0·2661	—
1400°	0·2691	0·2737	—	0·2690	—
1600°	0·2777	0·2763	—	—	—
1700°	0·281	0·277	—	—	—

* Before change into the higher modification. † After change.

Variations in the transition temperatures of quartz and cristobalite were found to depend on the state of division of the material, and with very finely divided quartz the transition point could be scarcely detected. The melting point of cristobalite was given as 1696°, whilst quartz was stated to be capable of melting between 1600° and 1670°, without conversion into cristobalite. Chalcedony was microcrystalline quartz. A. C.

21. The Binary Systems of Lithium Orthosilicate with Zirconium and Calcium Orthosilicates. R. SCHWARZ (*Zeitsch. anorg. Chem.*, 1921, **115**, 87).—The freezing point and density curves of the system lithium orthosilicate–zirconium orthosilicate indicated a compound having the formula $3ZrSiO_4,2Li_4SiO_4$. Similar curves for lithium orthosilicate–calcium orthosilicate showed the formation of a compound, Li_4SiO_4,Ca_2SiO_4, the range of existence of which commenced at 932°. A. C.

III.—Lamp-worked and General Scientific Apparatus.

22. Apparatus for the Determination of Methoxyl Groups. W. A. CUMMING (*J. Soc. Chem. Ind.*, 1922, **41**, 20 T).—This was designed to overcome the difficulty of securing complete absorption in pyridine found to occur in Robertson's apparatus when used according to Hewitt and Jones's method. The flask is of 250 c.c. capacity, *A* and *B* are ground glass joints, *T* a thermometer, and the absorption coils, *C*, are charged with 10—15 c.c. of pyridine. M. P.

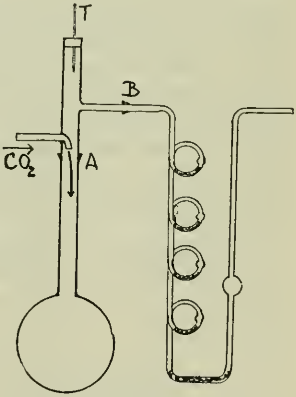

FIG. 3.

23. Graded Seal for Joining Pyrex to Lead Glass. W. C. TAYLOR and A. BAILEY (*J. Ind. Eng. Chem.*, 1921, **13**, 1158).—Graded glasses for making such a seal had previously consisted of mixtures of the two extremes and hence all contained lead which caused blackening during working. In addition, seven intermediate grades were needed to make the seal and some of these were liable to devitrification.

The authors succeeded in making a seal of five intermediate glasses, all of which were lead-free borosilicates.

The range of softening point of the glasses in the seal (defined as the temperature at which a rod 1 mm. diameter and 23 cm. long heated in a furnace 15 cm. long increased in length at the rate of 1 mm. per minute under its own weight) varied between 817° and 623° and the coefficient of linear expansion from $0{\cdot}0_532$ to

$0{\cdot}0_589$. The smallest differences in expansion lay between the extremes and the graded glasses immediately next them. This was necessary at the one end on account of the large difference in softening point between the glasses, and at the other by the large difference in viscosity and composition.

The method of making the seal was as follows. Starting at the low expansion (Pyrex) end, the two consecutive glasses were heated until their viscosities were approximately the same, and then the joint was blown to its finished shape. The glass of lower expansion was partly reheated in the cooling off so that on the final cooling it passed through a greater temperature range and thus more nearly approached the size of its nearest neighbour. This operation was repeated until the lead glass was reached and the seal was complete. M. P.

24. Importance of Standardising British Thermometers. (*Optician*, 1921, **64**, 150).—The advantage of the Government compulsory test of all clinical thermometers by the National Physical Laboratory was shown by the decreasing percentage rejections which had fallen from 25 per cent. initially to 5 per cent. and finally to 1·5 per cent. The compulsory testing of exported thermometers ceased in March, 1921, and the number tested dropped to 65,000 per month, as against 135,000 in November, 1919. When the compulsory test was abolished altogether there was a further drop to 55,000 per month, of which 4,000 were of German make. Great Britain was the first to see the necessity for compulsory testing, was thus the first to discontinue it and allow untested and therefore possibly inaccurate thermometers to find a market. The advisability of legislation to renew the compulsory testing was indicated. M. P.

25. Explosion of Artificial Eyes. A. S. Rochester (*Optician*, 1922, **63**, 13).—A number of cases of the explosion of Snellen artificial eyes had been recorded, some occurring whilst the eyes were being worn in the proper manner, others when they were stored away. The loss, in the latter case, was probably as large as a tenth of 1 per cent. of the eyes stored. The explosions occurred mostly in very hot or very cold weather, and the cause was the sealing of the back of the eye during manufacture, while the ball was at white heat, with the consequent production of a fairly high partial vacuum on cooling. Since the system was built up of many different types of glass, of varying thicknesses, it was thus very susceptible to extreme temperature changes. Attention was directed to the fact that the orbital discharge of certain patients was specially destructive to the eyes. A. C.

IV.—Decorated Glass.

26. The Application of Self-luminous Coloured Decorations in the Glass and Ceramic Industries. O. Parkert (*Sprechsaal*, 1922, **55**, 34).—The preparation of self-luminous paints, now coming into use in America and in France, depends on the use of phosphorescence phenomena such as are associated with the sulphides of the alkaline-earth metals, and of zinc sulphide. In addition to the sulphide, such as that of barium, strontium, or calcium, an active metal is added in the form of a salt of bismuth, manganese, or uranium. Further, a flux is needed, and is usually provided by a salt of lithium, sodium, or potassium.

A mixture which gives violet radiation is said to be obtained from 20 gm. calcium oxide, 5·5 gm. sulphur, 2 gm. starch, 1 c.c. bismuth nitrate solution, 0·12 gm. potassium chloride, 0·14 gm. sodium chloride. This mixture is heated for a lengthy period in a muffle at 1200°. For yellow colours, one may use 100 gm. strontium carbonate, 100 gm. sulphur, 0·5 gm. potassium chloride, 0·5 sodium chloride and 0·4 gm. manganese chloride. For a green colour, strontium thiosulphate 60 gm., uranium nitrate 6 gm., and bismuth nitrate 10—12 gm.; whilst for a red colour, barium carbonate 44 gm., sulphur 6·5 gm., lithium carbonate 1·2 gm., sodium carbonate 0·04 gm., rubidium carbonate 0·5 gm. may be used. The mixture is heated to glowing and appears to be most efficient when cooled rapidly. It should have a fine white appearance. Before use it is subjected to the action of strong illumination, which may be sunlight, or an incandescent gas mantle or a mercury vapour lamp.

For glass or ceramic processes, the preparation may be mixed into the liquid glass or applied as in the glaze to porcelain. It may also be applied as a paint or as a spray.

W. E. S. T.

V.—Optics and Optical Instruments.

27. The Interocular Distance. J. Weir French (*Trans. Optical Soc.*, 1921—2, **23**, 44).—A small Zeiss type pupilometer was used in making the measurements. The lowest interocular distance recorded by the author was 54 mm. in the case of an adult woman, and the highest value was 72 mm. in the case of a man. The average value for men was 63 mm., whilst for women it was 61 mm., the results obtained for women being consistently less than those obtained for men. For adults of both sexes, the average distance was 62 mm. All prismatic binoculars, and many Galilean glasses, being capable of adjustment, were suited to most people. A glass that was adjustable between the limits of 56 mm. and 72 mm. would suit all except a few young people, particularly women.

In the case of a Galilean glass, the lower value of 56 mm. placed a limit on the daylight diameter of the objective of 45 mm., that is, 21 lines, allowing 5·5 mm. for the thickness of the cell, tube, and sunshade. A binocular designed for the average distance of 63 mm. could have objectives with a daylight diameter of between 24 and 25 lines (52 mm.). Even in the case of specially large night objectives in prism binoculars, the prism arrangement could be made such that the separation of the objectives was greater than the interocular distance; hence the largest objectives likely to be needed could be introduced.

The usual limits for prismatic binoculars, namely, 57 and 70 mm., only excluded by the higher limit about 0·5 per cent. of the individuals tested, whilst the lower limit excluded 1·25 per cent. This small proportion of extreme cases did not warrant any alteration in the design of binoculars. V. D.

28. **Note on the Thin Astigmatic Lens.** T. CHAUNDY (*Trans. Opt. Soc.*, 1921—2, **23**, 56).—This paper deals mathematically with normal refraction occurring in a thin astigmatic lens, or a series of such lenses. V. D.

VI.—Illumination and Illuminating Ware.

VII.—Fuels, Refractories, and Furnaces.

29. **Sedimentation as a Means of Classifying Extremely Fine Clay Particles.** H. G. SCHURECHT (*J. Amer. Cer. Soc.*, 1921, **4**, 812).—A method was described for determining the rate of sedimentation of clays by measuring the suspended weights of a glass plummet suspended in a clay slip at different intervals of time. The specific gravity of the slip remaining in suspension might be calculated as follows :—

$$S = \frac{Pd - Ps}{Pd - Pw},$$

where S is the specific gravity of the slip, Pd the dry weight of the plummet in grams, Pw the suspended weight in distilled water, and Ps the suspended weight in the clay slip. The average weight of clay per cubic centimetre was calculated by using the following expression—

$$Cw = \frac{D\,(S - d)}{D - d},$$

where Cw is the average weight of clay per cubic centimetre, D the specific gravity of the slip, and d the specific gravity of water.

It was impracticable to separate, by elutriation, clay particles smaller than 0·003 millimetre which constituted 50 to 100 per cent.

of many clays. It was possible to classify particles as small as 0·001 millimetre by the plummet sedimentation method, and the results were more uniform than those obtained by elutriation.

F. W. H.

30. Osmosed Clay. H. Hirsch (*Ker. Rundschau*, 1921, **19**, 541).—A description of the Westerwälder Electro-osmose works at Staudt, near Montabaur, of which Fig. 4 is a section and Fig. 5 a ground plan. The factory adjoined the claypits, and the clay was conveyed into the second floor of the building

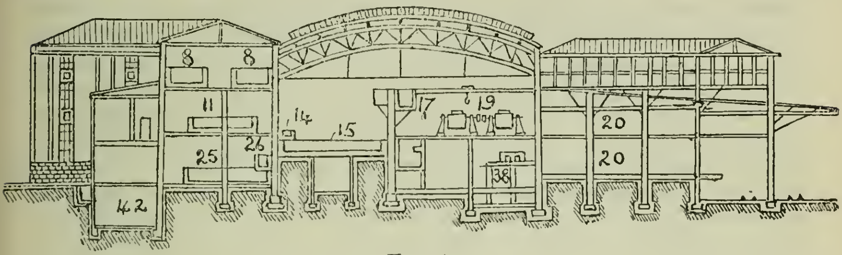

Fig. 4.

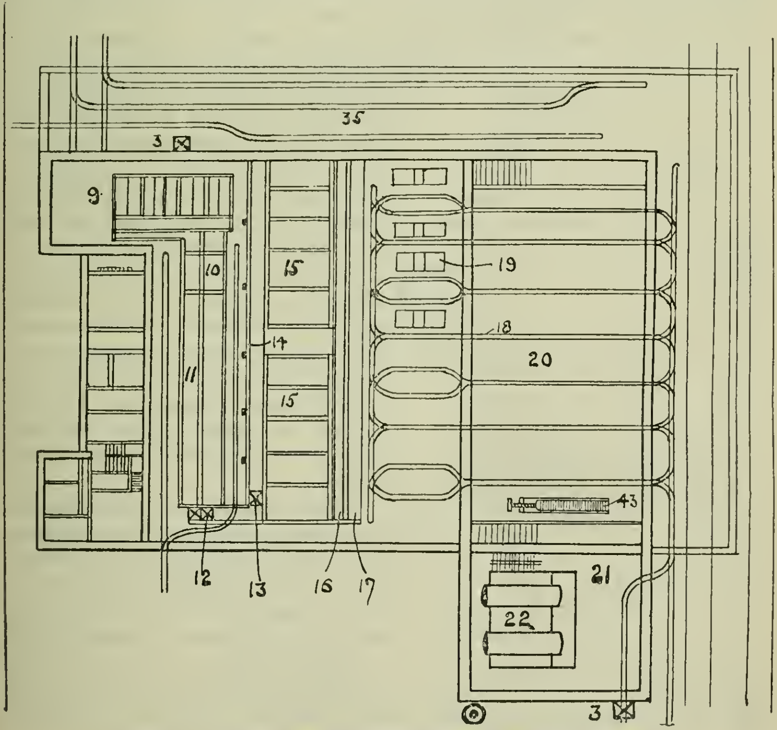

Fig. 5.—Ground Plan of Electro-osmose Factory.

by a cable tramway, and there disintegrated. A thin aqueous suspension of definite density was prepared by a blunger, 8, and stirrer, 9, after which the liquid passed to settling tanks, 10, where large sand grains were deposited. This stage was followed by the passage through long troughs, 11, most of the non-argillaceous impurities there settling out. At this point the conductivity was obtained, and, if necessary, corrections were made. A further journey over the shaking sieve, 12, and magnets, 13, led to a distributing trough, 14, and thence to settling tanks, 15, where the suspension remained several days, and deposited the last of the mechanically carried impurities. At the end of the settling period, the liquid gathered in the trough, 16, and was pumped into the distributing trough, 17, from whence it could pass into the electro-osmose machines under a regular and suitable head of pressure. An osmose machine illustrated in section in Fig. 6 consisted of a trough-shaped vessel, at the bottom of which were rotors, and above, a lead cylinder as anode, slowly revolving on its axis. The cathode was of brass wire netting, shaped to the under side of the anode. Clay suspension entered below, passed across the path of the current, and out into a side chamber. Clay particles were carried by the current to the anode, adhered to it, and were carried by its rotation out of the machine, there being removed by a scraper. From the machines was a wagon track to convey the clay to storage cellars, or to drying troughs, 20, where it was dried by steam from the boiler, 22. No more than 5 per cent. of moisture was allowed to remain, the clay being then suitable for grinding. The suspension passed from the machine to a distributing trough, 26, in the cellar, and was run into settling tanks, 25, to remove impurities freed by osmosis, after which it was pumped up for further use. A filter-press, 43, acting on the osmose principle was able to remove clay completely from suspension. Electric power was obtained by suitably transforming down a high voltage current.

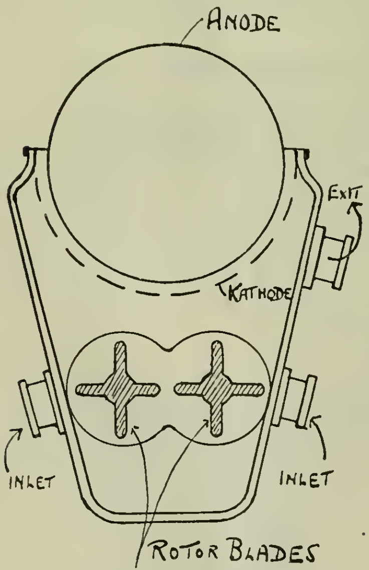

FIG. 6.—ELECTRO-OSMOSE UNIT.

The impurities originally in the clay were pyrites, mineral residues, and much quartz, the clay substance forming 60—66 per cent. of the material. Before treatment, the clay withstood temperatures up to Seger cone 31, had a relatively high sintering point, and had, on fusing, a bad colour, due to presence of pyrites. After osmosing, a clay content of more than 90 per cent. was obtained, a recent analysis showing the percentage composition: silica 49·27, alumina 33·56, iron oxide 1·30, lime 0·28, magnesia 0·05, potash 0·86, soda 0·36, loss on ignition 14·28. The osmosed clay stood up to Seger cone 33, burnt pure white, sintered at cone *O/a*, whilst its plasticity and stability were improved. A. C.

31. On the Plasticity of Clays. J. W. Mellor (*Trans. Ceram. Soc.*, 1921, **21**, 91).—It was probable that, other things being equal, the distribution of grain sizes which permitted the closest packing of the particles and exposed the maximum surface area would be most favourable to high plasticity. Agents which coagulated a clay slip enhanced the plasticity of the clay, whilst deflocculating agents diminished the plasticity. Plasticising agents such as gum, tannins, etc., probably acted indirectly by adsorption, although the plasticity of china clays practically free from organic matter showed that adsorbed organic colloids were not the source of their plasticity. There was an intimate connection between the past history of a clay in relation to its contact with water and its plasticity. This suggested that clay was slowly hydrated to form a colloid, but no difference could be detected in the plasticity of a clay after removing as much of its colloidal matter as possible. F. W. H.

32. Porosity. I. Purpose of the Investigation. II. Porosity and the Mechanism of Absorption. E. W. Washburn (*J. Amer. Cer. Soc.*, 1921, 4, 916).—The investigation of the nature and magnitude of the errors involved in determining porosity by the commonly used methods was undertaken with the purpose of throwing some light on these questions and, if possible, of evolving a procedure for porosity measurement which would meet the requirements of a standard reference method. The requirements of an engineering testing method were simplicity, rapidity, and convenience with no more accuracy than practical considerations justified. There was needed, however, a laboratory method where accuracy was the chief requirement.

Six types of pores were described, the closed or bubble pore, the channel pore, the blind-alley pore, the loop pore, the pocket pore, and the micropore. Definitions were proposed for certain terms used in porosity measurement. Permeability was the readiness with which the body permitted a fluid to flow through it from one side to the other. Penetrability, as a physical quantity, was defined as the ease with which a liquid was drawn into the pores of the body by capillary action, without attendant chemical action between the body and the liquid. The absorptivity on complete immersion, determined by a combination of its penetrability, permeability, and porosity, was the amount of liquid absorbed by a test-piece completely immersed with all its surface pores open, and was a function of the time of immersion and of the surface tension and viscosity of the immersion liquid. Porosity was taken to be the open-pore porosity. Bulk or apparent density was the ratio between the mass of the test-piece to its volume whilst the true density was best determined by the pyknometer method applied to the finely-powdered material. Closed-pore space was calculated from the true density, the bulk density, and the porosity. Cracks and holes were spaces in a body so large that they could not be counted in, in determining the porosity, and the method used for measuring porosity should, if possible, be one which could be depended on to reject such spaces.

The permeability was determined by the rate at which the body permitted some standard fluid, either a gas or a liquid, to flow through unit area and unit thickness of the body under some specified pressure head. The penetrability might be measured by the amount of a standard liquid which, in a stated time, a standard test-piece would absorb at a stated temperature, when a given surface of the piece, in a determined position (horizontal or vertical), is kept in contact with the liquid and the air surrounding the test-piece is kept saturated. The bulk density was conveniently and accurately determined by weighing the completely saturated test-piece suspended in any suitable liquid or by means of a volumeter method, using mercury as the liquid. F. W. H.

33. Porosity. III. Water as an Absorption Liquid. E. W. Washburn and F. F. Footitt (*J. Amer. Cer. Soc.*, 1921, 4, 961).—The authors found the ordinary immersion method in water and simple immersion in a low vacuum without boiling to be untrustworthy. Adsorbed water vapour might cause errors up to 2 per cent. in the porosity value. It was found also that a perfectly dry piece of burned clay was a more powerful drying agent than calcium chloride or sulphuric acid, since it would absorb water from either of these materials. The gain in weight in these circumstances was, however, too small to have any practical significance in connection with porosity determinations. Boiling the clay in water at atmospheric pressure produced a gradual and continuous rehydration of the clay, and errors from this source might amount to 3 per cent. besides the error from dissolved material, which might amount to 2 per cent. during a period of three hours' boiling.

The most accurate method of carrying out the vacuum soaking method with water was as follows : The test-pieces, the dry weights of which had been determined, were placed in the vacuum vessel and the air was evacuated until, on closing the connection to the pump, the manometer reading remained constant. The pump connection was then closed and enough air-free, cold, distilled water admitted to cover the test-pieces. The pump was disconnected, the vacuum broken, and the test-pieces were allowed to soak until the water had completely penetrated the pores. Following soaking, the test-pieces were removed, " dried " by wiping with a very damp cloth, and weighed in a weighing tube to prevent loss by evaporation during the weighing. For this method a good pump was necessary, and also a minimum soaking period. Methods for calculating the pressure required in the vacuum vessel for any particular fractional accuracy desired and for calculating the minimum soaking period for a given test-piece and a given liquid of known penetrativity were given. This procedure in the vacuum method, employing cold water and avoiding boiling or stirring, reduced both rehydration and solution to a minimum, since the temperature was low and any dissolved material could escape from the test-piece only by diffusion, which was a relatively slow process. The method was not, however, recommended as a primary standard. F. W. H.

34. Porosity. IV. The Use of Petroleum Products as Absorption Liquids. E. W. WASHBURN and E. N. BUNTING (*J. Amer. Cer. Soc.*, 1921, **4**, 983).—The advantages of petroleum products were that slaking, chemical action, adsorption, and solvent action were avoided, although a longer soaking period was necessary. Paraffin and vaseline were, both of them, materials with a high fluidity when hot and a comparatively low fluidity when cold. They permitted of the surface of the saturated test-piece being brought to a definite and reproducible condition with all the surface pores full. Paraffin might be used, but vaseline was preferable, because it underwent no change of phase on cooling. The following figures were obtained in tests on the comparative values of water and vaseline as saturation liquids :—

	Dry weight in grams.		Pore volume in c.c.		
Material.	Original.	After removal of water.	With water.	With vaseline.	Diff. per cent.
Briquette No. 1	83·987	83·988	8·22	8·40	2·2
Briquette No. 2	89·113	89·115	9·15	9·41	2·7
Porous white ware tile	26·191	26·193	4·48	4·54	1·3

The results obtained with vaseline were higher than with water, and the author considered they should be given the greater weight, since, with the knowledge that we had of the chemical and physical properties of the class of hydrocarbons to which vaseline belonged, it was difficult to imagine any source of error which would cause vaseline to give results higher than the true values, whilst it was not difficult to understand how the results obtained with water might be low by the amounts indicated. As a general rule, the vaseline method might be used to advantage where the accuracy desired was such as to require careful attention to the surface condition of the test-piece after removal from the absorption vessel or whenever errors due to the action of water on the body were to be feared. Owing to the long soaking time required, the method was, however, not a satisfactory one to use with bodies having a considerable volume of very small pores. F. W. H.

35. Porosity. V. Recommended Procedure for Determining Porosity by Methods of Absorption. E. W. WASHBURN and E. N. BUNTING (*J. Amer. Cer. Soc.*, 1922, **5**, 48).—The authors described the operations to be employed with shaped test-pieces under the headings, "Preparation of the Test-piece," "Determination of the Dry Weight," "The Absorption Apparatus," "Preparation of Standard Vaseline," "Saturation Procedure," "Calculation," and "True Density." After soaking in vaseline in a vacuum and also boiling for a few minutes, the percentage porosity was given by the expression

$$\frac{100\,(W_g - W_d)D_w}{(W_s - W_h)D_s},$$

where W_s is the weight of the test-piece with pores full of absorption liquid (where vaseline was used excess was scraped off and the test-piece wiped with chamois leather); W_d the constant dry weight after the test-piece had been allowed to stand for a few hours in a vacuum over 95 per cent. sulphuric acid; W_h the weight of the soaked test-piece suspended in water (or other suitable liquid); D_w the density at room temperature of the water or other liquid used for determining the suspended weight, and D_s the density of the absorption liquid (vaseline, etc.) at the same temperature.

A new and accurate pyknometer method for determining porosity by absorption was described. The method was applicable to shaped test-pieces or to granular material. A pyknometer of weight W_p gm., capacity V_p c.c. (at the "setting" temperature), and having a form equivalent to that shown in Fig. 7 was employed. The bulb was filled with a coarsely granular, sieved, and dried sample of the material and its weight, W_1, obtained. It was then evacuated through A until the pressure fell to less than $\frac{ABV_B}{V_P}$, where B was the barometric pressure, A the fractional accuracy desired in the result, and V_B the bulk volume of the sample of material. Mercury was admitted through B until the apparatus was full and the mercury level in A was some distance above the stopcock. B was then closed and the vacuum adjusted until, at room temperature, the manometer reading plus the distance h (from the centre of the bulb to the mercury level in A) was equal to $0{\cdot}05/d$ cm., where d was the diameter in centimetres of the largest opening which it was desired to class as a pore, all larger openings being classed as holes or cracks. Stopcock A was closed, the pump disconnected and all mercury removed from above both stopcocks.

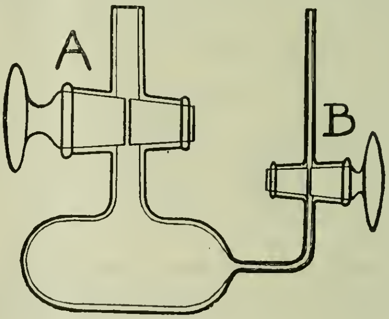

FIG. 7.

A or B was opened and the weight, W_2, of pyknometer and contents determined. The bulk density D_B of the material was calculated from the following formula

$$D_B = \frac{(W_1 - W_P)D_M}{D_M V_P - W_2 + W_1},$$

where D_M was the density of mercury at the temperature when the mercury was adjusted to height h.

For saturation, the contents of the pyknometer were removed, the sample of material was separated completely from the mercury and returned to the pyknometer. If necessary, a new sample of the material might be used. The pyknometer and contents were again weighed, W_1'. The apparatus was then evacuated until the pressure was not greater than AB, where B was the barometric pressure and A the fractional error permissible. The absorption liquid was admitted until the apparatus was full. Water might be used if it was without action on the material, otherwise carbon tetrachloride, benzene, or any other suitable pure organic liquid might be employed. With stopcock A closed and B open, the apparatus was allowed to stand at room temperature, $t'°$, for the necessary soaking period. B was then closed, all excess liquid removed from above both stopcocks, and the weight, W'_2, determined. The percentage porosity, x, was calculated by using the following expression :—

$$x = 100\left[1 - \frac{D_L V_P - W'_2 + W'_1)D_B}{D_L\,(W'_1 - W_P)}\right],$$

where D_L was the density of the absorption liquid at the temperature $t'°$. The theory of the method was discussed at length. Among other advantages, it gave the operator control over the maximum size of opening which he desired to class as part of the pore space. It could also be made to indicate directly the necessary soaking period.
F. W. H.

36. The Dehydration of Dried Clays. J. W. Mellor, N. Sinclair, and P. S. Devereux (*Trans. Ceram. Soc.*, 1921, **21**, 104).—The authors found that clays gradually lost some of their so-called combined water at ordinary temperatures. This change was reversible and water was restored in a moist atmosphere, showing that no drastic change had occurred in the structure of the clay molecule. This change was totally different from that which occurred when water was expelled at higher temperatures. This "over-dried" clay had some important properties. The resorption of water was so very slow and required so long a time to restore the original plasticity that the working qualities, plasticity, shrinkage, etc., of certain troublesome clays could be modified by desiccation. The dried clay approached the condition of many unweathered fireclays in requiring exposure to a moist atmosphere for a long time before the original plastic condition was resumed. The custom of seasoning glass pots for a few months in a warm, dry place might not really be so redundant an operation as might at first sight be supposed. From this point of view the storing of clays in a warm, dry spot was not conducive to their subsequent working in their most plastic state. F. W. H.

37. A Study of some Bond Clay Mixtures. D. H. Fuller (*J. Amer. Cer. Soc.*, 1921, **4**, 902).—In attempting to produce results from certain American clays equal to those obtained from Grossalmerode clay in glass pot bodies, the author found it was not possible to duplicate the physical properties, particularly the low water of plasticity and low drying shrinkage of the Grossalmerode clay. Several of the mixtures, however, gave better results as regards resistance to corrosion of glass batch than the one containing the Grossalmerode clay. F. W. H.

38. Silica Bricks. P. Schneider (*Tonind. Zeit.*, 1921, **45**, 452).—Silica bricks which had been made in a manner similar to sand-lime bricks were examined and the following properties determined, compression strength, volume shrinkage, density, percentage absorption, and softening point. Lime and fireclay grog tended to decrease the refractoriness excessively, whilst clay, used in conjunction with lime, retarded the cementing action and prevented to a certain extent the formation of calcium hydrosilicates. F. W. H.

39. The Possibility of Preparing High Grade Silica Bricks from Quartzite Rock. E. Lux (*Stahl u. Eisen*, 1921, **41**, 258).—Silica bricks could be made from tertiary quartzites of a quality corresponding with those made from tertiary quartz. Under the microscope the quartzite bricks showed a high degree of transformation. This transformation was obtained in the quartzites by high temperature burning such as was used in America. German silica bricks did not usually show such a high degree of transformation, but microscopical examination of the better types of brick showed that if the method of manufacture were chosen according to the character of the raw material, a brick might be obtained not inferior in quality to bricks made from tertiary quartz. F. W. H.

40. A Comparative Study of American and German Quartzites as Raw Materials for the Silica Brick Industry. K. Endell (*J. Amer. Cer. Soc.*, 1921, **4**, 953).—The author determined the chemical composition, cone fusion temperatures, microstructure, in the raw state and after finings, and the velocity of inversion after successive finings, of certain German and American quartzites. After a single firing to 1435° the German erratic block quartzites of the tertiary age showed much greater expansion than the American variety. Hessian quartzites resembled the American. The use of the German erratic block quartzites for the manufacture of silica brick of the highest quality was more economical, both in preparation and burning costs, than the use of American quartzites. F. W. H.

41. Behaviour of Refractory Materials under Load at High Temperature. K. Endell (*Stahl u. Eisen*, 1921, **41**, 6).—The author examined the behaviour of refractories under a pressure of 1 kilogram per sq. cm. He divided refractories, according to the results obtained, into four groups. Fireclay bricks which had a refractoriness of about 1730° began to soften at 1300°, a 50 mm. cylinder being reduced to 30 mm. in a test lasting four and a half hours, during which time the maximum temperature reached was 1500°. Bricks made from very plastic clay softened at 1150°. Magnesite bricks which had a refractoriness of more than 2000° softened at 1500°, the softening being due to the binding agent. A 50 mm. cylinder of this material was reduced to 10 mm. in a test lasting four and three-quarter hours, the maximum temperature reached being 1650°. Silica bricks of a refractoriness in the region of 1750° did not soften below 1650°. After heating for just above four hours they broke in pieces at a maximum temperature of 1680°. Bricks made of carbon with a refractoriness above 2000° did not soften, the cylinders used being unaffected during a test lasting five hours in which a maximum temperature of 1720° was attained. A 4 per cent. reduction in volume occurred, however, due to the burning away of some of the carbon. F. W. H.

42. Refractories under Load Conditions. H. J. Knollman (*J. Amer. Cer. Soc.*, 1921, 4, 758).—The chief factors controlling the life of slabs were stated by the author to be (1) proper selections of clays and grog, (2) medium absorption or porosity, (3) strength in the unburned state, (4) proper and thorough blending and preparation of the batch, (5) proper pressing so as to ensure freedom from flaws, (6) proper drying, (7) proper setting in the kilns, and especially (8) the initial heating. These factors were briefly discussed. The manner of setting grinding wheels, using large slabs, was described and the influence of the rate of heating, size, and shape of the slabs on the life of the articles was discussed. When not due to structural defects, failure at high temperatures was brought about by a gradual decrease in mechanical strength between each heating, so that fireclay slabs under transverse load at such temperatures had decided limitations. F. W. H.

43. Casting Refractory Materials. M. de Roiboul, Paris (Brit. Pat., No. **165051**. September 14th, 1920. Convention date, June 15th. Not yet accepted).—Refractory minerals belonging to the silica or alumina group, such as sand, rock-crystal, quartz, alumina, corundum, and the like, are fused in a crucible, *a*, made of refractory oxide such as oxide of zirconium, yttrium, thorium, or erbium, or mixtures of such oxides. The crucible is surrounded by an insulating wall, *b*, enclosed in a casing, *c*, of refractory bricks. Current is admitted at *d* and passes to a semicircular ring connected by vertical carbon rods to a conducting ring at the lower part of the furnace, this ring being connected by vertical carbon rods to a second semicircular ring in connection with the terminal, *l*. The current passing through the carbon rods raises the temperature to 500°. The electric circuit is then completed through the crucible between the terminals, *m* and *n*. The charge, which fuses between 1800° and 2700°, flows through a top hole, *p*, controlled by a slide, *q*, into a mould, *s*, of ordinary sand faced with refractory oxide, *t*. The castings may be cooled quickly by exposing the mould to the air or slowly by exposure to progressively reduced temperatures in an electric furnace or by enclosure in a heat insulator. The castings are stated to be applicable for electric insulators and gems and as substitutes for optical or ordinary glass, for porcelain, faience, bricks, terracotta, ferro-concrete, stone, for steel in castings, for engines for aeroplanes, motor-cars, marine work, locomotives, machine tools, rails, wheels, screws, nuts, cannon, armour plate, turbines, and ball-bearings. As an example, the following composition for the crucible is given : Zirconium oxide 60 per cent., yttrium oxide 15 per cent., thorium oxide 5 per cent., and erbium oxide 20 per cent.

H. G. C.

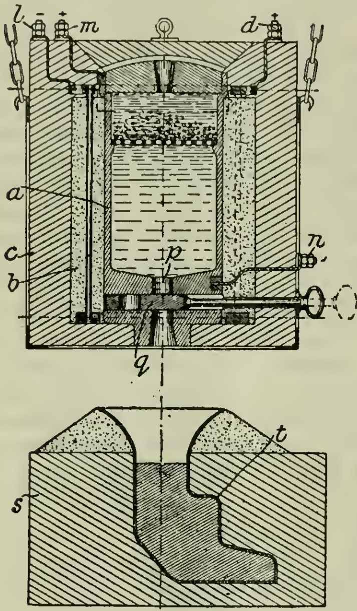

Fig. 8.

44. A Regenerative Glass Furnace. W. P. Thompson, Liverpool, and Soc. Anon. Fours et Procédés Mathy, Liége, Belgium (Brit. Pat., No. **164991**, August 11th, 1920).—In a regenerative furnace of the kind having gas and air supply ports and ports for the escape of combustion products arranged at each side of the working chamber, regenerators surmounted by three flues are arranged at each side of the furnace, one of the flues being employed for conveying combustion products from the working chamber to one or other of the regenerators and the other two flues for conveying air and gas to the burners. Valves are provided and may be operated so that, (1) flames issuing from the burners on one side of the working chamber pass to outlet flues on the opposite side, (2) flames issuing from the burners on one side of the working chamber escape through outlet flues on the same side, or, (3) flames issuing simultaneously from burners on both sides of the working chamber escape through the outlet flues located on both sides. The course of the gases in the first of these methods of operation is shown in Fig. 9 (*a*). Reversing-valves, 18, 20, control the admission of gas and air, respectively, to regenerators, 9, 8. The heated gas and air pass through the open valves, 7, 6, and gas and air conduits, 4, 3, to the burners, 12, and the combustion products escape through ports, 15′, to a conduit, 2′, part of the gases escaping to the regenerator, 8′, and the remainder by way of a by-pass flue to the regenerator, 9′. The gases leave the regenerators and escape to the chimney, by way of the reversing-valves, 18, 20. The second method of operation is shown in Fig. 9 (*b*). The air only is preliminarily heated, gas being led directly into the flue, 4, which is shut off from the chamber in which the valve, 7, is located. Air passes through the reversing valve, 18, to the regenerator, 9, and thence through the port controlled by the valve, 7, and port, 26, to the flue, 3, and burner, 12. The combustion products escape through the ports located on the same side of the furnace and enter the flue, 2, which is in communication with the regenerator, 8. By opening the valves 6, 10 and closing the valves 5, 7, the air may be led through the regenerator, 8, and combustion products through the regenerator, 8. In the third method of operation of the furnace, the burners at both sides of the working chamber and the valves are operated in a similar manner to that described in connection with Fig. 9 (*a*). The horizontal conduit of each burner, 12, is of such a length that the hottest part of the flame is near the mouth of the burner. H. G. C.

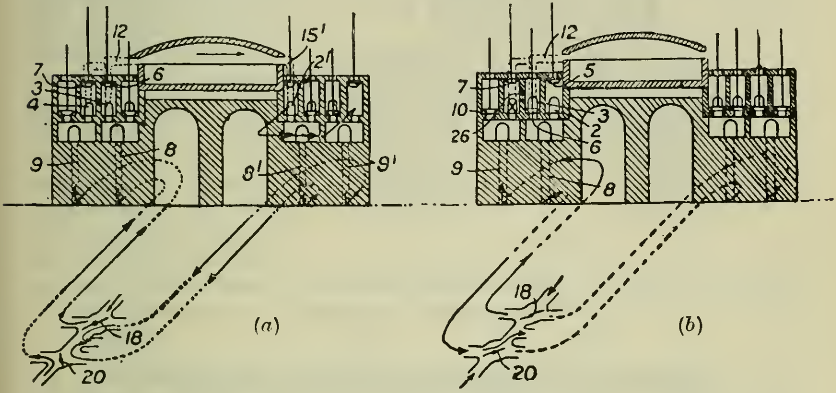

Fig. 9.

45. Glass Furnaces. W. G. Clark, New York, U.S.A. (Brit. Pat., No. **163995**, May 27th, 1921. Convention date, May 27th, 1920. Not yet accepted).—The delivery trough of a glass furnace is heated electrically in order to facilitate starting up from cold. For this purpose the trough, 4, embodies resistances, 9, connected up to leads, 12, 13, of an electric circuit. In conjunction, or, it may be, alternately with this method of heating, an alternating current may be passed through the glass itself. The trough comprises the usual riser portion, 5, and outlet, 7. H. G. C.

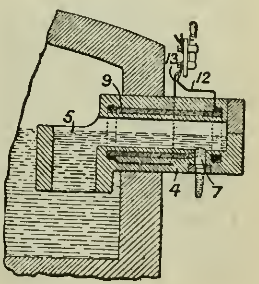

Fig. 10.

46. A Recuperative Gas-fired Glass Tank Furnace. M. W. Travers, London (Brit. Pat., No. **165628**. May 18th, 1920).—In a glass-melting furnace, an underfed gas producer, *C*, is arranged at each side of the melting end of the tank, and is connected thereto by a short flue, *D*, into which hot air from a recuperator is delivered through the connection, *M*. The heating-gases pass from the melting-chamber, *A*, through a port, *I*, to the working-chamber, *B*, and thence through ports, *J*, to recuperators arranged alongside the gas-producers. H. G. C.

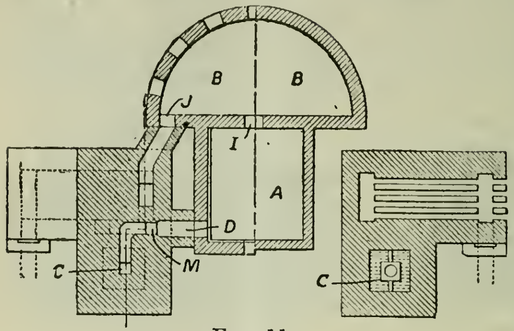

Fig. 11.

47. Devices for Controlling Glass Furnaces. E. W. Harvey Gas Furnace Co., Ltd., and E. W. Harvey, London (Brit. Pat., No. **162232**, September 16th, 1920).—In a gas-fired glass-melting furnace heated by one or more reversible flames, supplementary ports are provided near the gathering or tapping holes, through which a portion of the heating-gases is drawn, under the control of dampers, by a draught stronger than that serving the main ports. The supplementary ports may, for example, be connected directly with the chimney instead of through the regenerators. The invention applied to tank furnaces heated by transverse and horse-shoe flames, and to circular and rectangular pot furnaces. H. G. C.

48. An Oxy-acetylene High Temperature Furnace. H. Wilson (*J. Amer. Cer. Soc.*, 1921, **4**, 835).—A detailed description with drawings was given showing the use of oxy-acetylene gas in a small furnace for testing refractory cones. For fire-clay fusion temperatures, alundum, magnesia, and alundum-magnesia mixture had been used successfully for lining the furnace. The author suggested the following change in the Ceramic Society's specified rate of heating for cone fusion tests : " The rate of heating shall not exceed that corresponding to one-half a cone (approximately 10°) per minute within a range of ten cones below that of the final fusion cone, and this rate shall preferably be reduced to one cone per five minutes within two cones of the final cone of fusion." F. W. H.

49. A High Temperature Testing Furnace. W. M. Hepburn (*J. Amer. Cer. Soc.*, 1921, **4**, 755).—A description was given of a surface combustion furnace lined with alundum and fed by seven burners supplied from a mixture box in which an explosive mixture of gas and air was made by the use of a special inspirator. Seger cone 36 was melted down in one hour, the furnace using 156 cubic feet of towns gas. The maximum temperature attained was 3400° F., being within 200° F. of the theoretical maximum. The advantages claimed for the furnace included simplicity, low fuel consumption, ease of observation and measuring temperatures, and the ability to produce at will a neutral, reducing, or oxidising atmosphere. F. W. H.

50. An Improved Recuperative Tank Furnace. L. LE BRETON MOUNT, London (U.S.A. Pat., No. **1395591**, November 1st, 1921. Filed May 6th, 1920, No. 379203).—The invention consists of a tank furnace particularly intended for working in conjunction with a flow-feed, and is of the type in which the air supply is preheated by passing through a recuperator. As shown in longitudinal section in Fig. 13, the air entering at *d* passes beneath the bed of the tank, *a*, then travels upwards between and around the refractory recuperator tubes, *m*, and then to the burner, *e*, along channels, *f*, above the crown. The hot gases, after leaving the tank, pass through the tubes, *m*, and then travel through

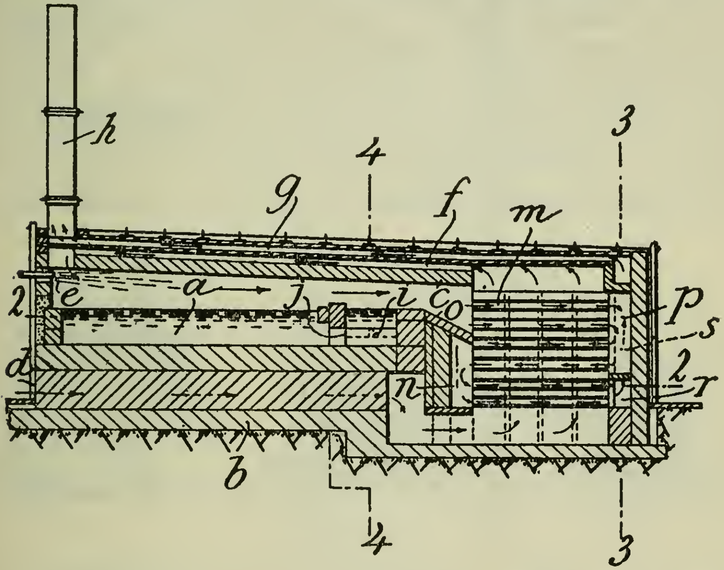

FIG. 12.

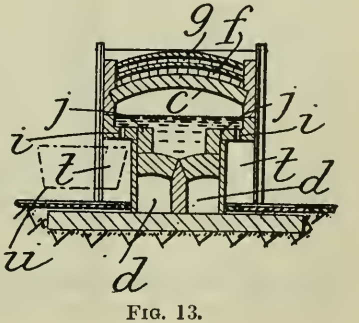

FIG. 13.

passages, *g*, placed above the channels, *f*, to the stack. The tank is fitted with a bridge, and behind this bridge the floor of the tank is raised at the sides, as shown at *j*. Flow-feed openings, *l*, *i*, are formed in the raised portions, *j*, and recesses, *t*, are formed in the sides of the tank below the raised portions to accommodate forming-machines, *u*. By this means, the moulds of the machines can be brought immediately beneath and close up to the openings, *i*, and the position of these openings enables the metal to be kept sufficiently fluid without the necessity of using extra heating-devices. G. D.

51. An Improved Tank Furnace. J. E. Hurley, Jeannette, Pa. (U.S.A. Pat., No. **1390614**, September 13th, 1921. Filed June 15th, 1920, No. 389191).—Relates to a tank furnace described and illustrated in U.S.A. Patent No. 792705 in which the side walls consist of water chambers, 3, with a wood facing. According to the present invention, in order to give further protection to the walls of a tank of this character, means are provided for circulating the water between the walls of the chambers, 3, and the wooden facing.

As shown in sectional elevation in Fig. 14, the chambers, 3, are formed of metal plates riveted together and braced by angle-bars, 4, water being admitted through the open top of the chamber from pipes, 15. The inner plates, 7, are preferably formed with lower portions, 8, vertical and upper portions, 9, inclined as shown, the top plates being bent to form a trough, 10. A wooden or other fibrous lining, 11, is secured to the plate, 7, and a layer of spacing material, 13, such as wire mesh is interposed between the wood and the plates, 7, to form a passage through which water can circulate. The crown, 17, of the furnace has a depending portion, 18, which extends into the trough, 10.

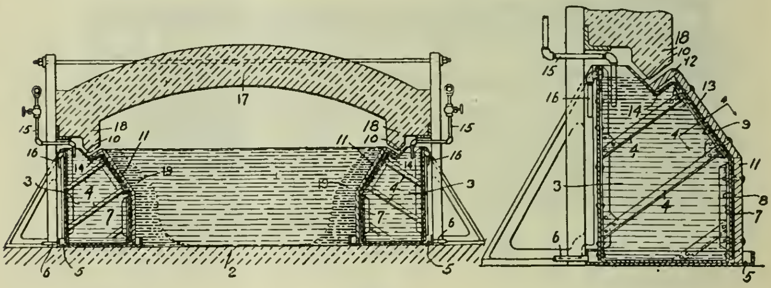

Fig. 14.

In use, a chilled layer, 19, of glass is formed along the sides of the tank and this layer extends into the trough, 10, thus anchoring the chilled glass and sealing the side of the tank. The circulation of water behind the wood prevents it from being consumed.
G. D.

52. A Furnace Temperature Regulator. H. S. Roberts (*J. Washington Acad. Sci.*, 1921, **11**, 401).—The apparatus consists of a Wheatstone bridge of which the electric furnace forms one arm, the supply voltage being applied at opposite corners, through a variable rheostat as in the sketch. The remaining corners of the bridge are connected to a millivolt-meter, *A*, of 50 ohms and period $\frac{2}{5}$ sec., which has the ordinary pointer replaced by a contact arm or "boom" moving between two contact studs. The boom of *A* connects through the winding of a polarised telegraph relay, *B* (2000 ohms), to the boom of *B* and to the winding of a main line telegraph relay, *C* (150 ohms), operated by current from the main supply, and to the right hand contact stud of *A* through the 150 ohm resistance, R_1. A thermal "Lamp Flasher," *F*, in the primary circuit, *P*, of an ordinary bell transformer (110/8 V) run from the supply mains, produces intermittent changes in the current through *P*, with corresponding induced currents in the secondary *S* which is in series with the galvanometer. This has the effect of producing violent "kicks" on the boom of the latter which suffice to ensure good contact being made even when the contacts are slightly greasy. The remainder of the apparatus, being connecting wires and resistances, should explain itself. The best value for R_3 is about $\frac{1}{3}$ that for the furnace itself, which should be 2·5—10 ohms when hot.

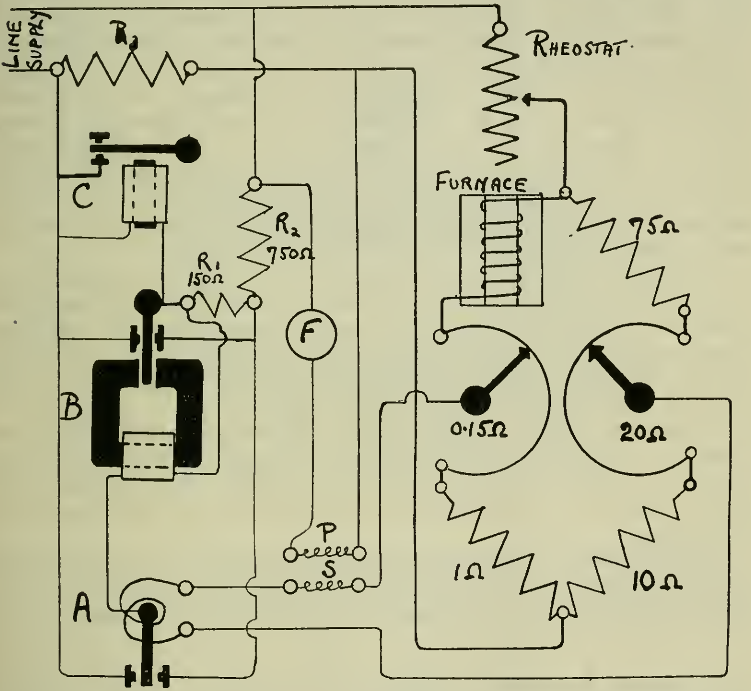

Fig. 15.

All the resistances should have a low temperature coefficient of resistance and be of ample current-carrying capacity.

To follow the working, assume a rise in furnace temperature above the desired mean so disturbs the balance of the bridge that a current passes through A moving the boom to the left-hand stud and that, on making contact there, the current through B causes its boom to move over to and touch the left-hand contact. When this happens C is short-circuited and the main current has to pass through R_3, that is, the furnace is cooling. As it does so, the boom of A will begin to move to the right until it touches the other stud causing the boom of B to move towards the right-hand stud, when C is no longer short-circuited, but comes into action, cutting out R_3 and so increasing the current through the furnace, which heats up. When the boom of B touches the right-hand stud it short-circuits R_1 and also the current through its own coils and through the right contacts of A. As it is polarised, however, the boom is kept over to the right by the permanent magnets of B, until the furnace is heated sufficiently, when the balance of the bridge is again disturbed and the boom of A swings over to the left to repeat the above cycle.

The supply current was 110 volts, direct, and the amount was of the order of 15 amperes—no more. Only direct current had been used by the author, but it was suggested that by using an alternating current galvanometer and a separate source of direct current to operate the bell transformer the apparatus would function correctly with alternating current.

It was stated that a platinum wound furnace could be kept at 1250° to ± 0·1° for hours without external manipulation, and that at 1450° the furnace cooled at the rate of 2—3° per hour, which could be compensated by a slight manual adjustment of resistance.

When used in preparing heating and cooling curves, the 75 ohm coil of the bridge was advantageously shunted by a rheostat giving 1000—2000 ohms in 10-ohm steps plus a 10-ohm slide wire.

M. P.

53. Glass Annealing Lehr. E. E. Milner and W. J. Lytle, Assignors to H. L. Dixon Company, Carnegie, Pa., U.S.A. (U.S.A. Pat., No. **1361604**, December 7th, 1920. Filed August 1st, 1919, No. 314615).—This invention refers to the muffle type of lehr in which the glassware does not come into contact with the flames or products of combustion, but is heated by radiation from the flue walls. By the arrangement of flues as disclosed, it is claimed that a uniform annealing temperature is obtained and that the temperature is very easily regulated and controlled.

Producer gas is led into a series of longitudinal flues, 10 (Fig. 16), which form the base of the lehr. Each of these flues has a vertical flue, 13, so as to form the sides and crown of the lehr, and thus act as the main heating flues for the receiving end of the lehr. These flues, 13, are arranged so that the two from one side alternate with the two from the other side, with the results that the products of combustion flow round the annealing chamber in opposite directions, thus giving substantially uniform heating. Preheated air is supplied to the flues, 13, through the openings, 15, from the longitudinal flues, 14, each of which has an independent air inlet, controlled by a damper. The return from each flue is into one of two chambers, 19, which are located immediately above the flues 14. From these chambers, the hot gases are carried away by flues passing up the sides and over the top of the annealing chamber to the stack, 22.

The inner walls of the flues, 13 and 20, form a practically continuous heating surface for the lehr chamber. The outer walls of these flues are composed of a series of blocks, 24, whilst the inner walls consist of a series of tiles or slabs, 25. These slabs have bevelled edges so as to form mitre joints, and have paralleled faces, thus reducing their thickness and increasing their heat transmission. The roof or arch blocks, 27, are supported from the iron framework, 7, by long hanger bolts. The floor of the heating chamber is also built up of tiles or slabs, 30, which are supported on the partition walls of the flues, 19. It is claimed that such a method of construction greatly facilitates the carrying out of repairs with a minimum loss of time. S. E.

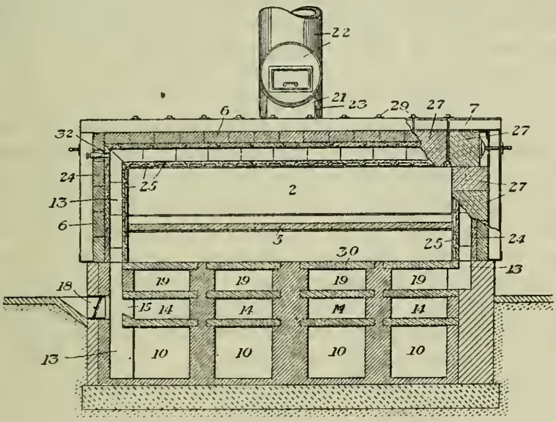

Fig. 16.

54. The Construction of a Novel Testing Furnace. S. F. Walton (*J. Amer. Cer. Soc.*, 1920, **3**, 833).—A simple form of gas-fired furnace for use in testing the modulus of rupture of refractory materials was described. It was built in cylindrical form of carborundum bricks backed by one and a half inches of rammed kieselguhr and four and a half inches of firebrick. The gas ports were set tangential to the wall of the furnace. For making the cross-breaking tests a lever arrangement was used, one end of the lever pressing through a knife edge of refractory material on the test-piece, which rested on knife edges embedded in the floor of the furnace. The other end of the lever was connected with a chain jack having a handle fitted to the sprocket wheel and set on a platform scale. A bucket hung from the balance arm of the scale and was loaded with water from a Marriotte bottle.

F. W. H.

55. Design of Open Hearth Furnaces. A. D. Williams, (*Iron Age*, 1920, **105**, 35, 119).—In the pig and ore process, the temperature of the metal in the bath was 1525—1600°, whilst the gases leaving the hearth ranged from 1600—1700°. Yold stated that the gases remain on the hearth two seconds, whilst Groume-Grjimailo assumed the temperature drop through the hearth as 200° per second. It required from one to two seconds for complete combustion, owing to the time taken for the jets of gas and air to mix. Where gas and air were preheated to 1000—1200°, the theoretical flame temperature was 2100—2200°, but actually, as indicated by a Wanner pyrometer, it only reached 1800—1850°. Knowing the quantity of the fuel gasified in the producer, it was possible to find approximately the volume of gas supplied, and the amount of air necessary for combustion, and from these the velocity of gas through the ports. Thus a 30 ton furnace making four heats a day consumed 0·347 kg. of coal per sec., corresponding with 1·81 cub. m. of gas and 2·52 cub. m. of air per sec. at 0° and 760 mm. pressure. At 1000°, the volumes entering the heating chamber would be 8·44 cub. m. and 11·77 cub. m., respectively. In open hearth furnaces, the ports were just below the roof, and the hearth formed a pocket which became filled with the coolest gas in the chamber. It was found possible to jet the flame into this by arranging the direction of the ports and adjusting the velocity of gas and air. In European furnaces, the velocities ranged from 12 to 18 m. per sec., in America they were as high as 50 m. per sec. Since it was necessary for the flame to lick the furnace bottom, the depth to which it was projected must be sufficient to ensure this. The relationship between drop of flame and the factors which govern it was : $h = \frac{v^2 \sin^2 a}{2g} \times \frac{p_m}{p_l - p_m}$, where v was the velocity, a the angle to the horizontal of the projection, g gravitational force, p_m the specific weight of the fluid in motion and p_l its weight at rest. Developed and simplified, the expression became $h = \frac{v^2 \sin^2 a}{2g} \times \frac{273 + t_l}{t_m - t_l}$, and for a vertical jet $h = \frac{v^2}{2g} \times \frac{273 + t_l}{t_m - t_l}$, in which t_m was the temperature in degrees centigrade of the gas in motion, t_l that of the gas at rest. The application of the Yesmann formula to a number of 30-ton furnaces is given in Table I, to obtain the velocities given in columns 2 and 4. Columns 7 and 8 give the resultant angles and flame velocities, which must be found by the parallelogram of velocities. Column 9 gives the minimum temperature of the gases in the heating chamber at which the jet of flame will lick the bottom. Table II shows the maximum and minimum of hearth dimensions of a number of furnaces in service. With too short a furnace, the flame would extend beyond the hearth; with too long a furnace, the gases of combustion would tend to drop below the bath temperature.

TABLE I.

Area of gas port. Sq. M.	Velocity of gas at 1000° M/S.	Area of air port. Sq. M.	Velocity of air at 1000° M/S.	Inclination of gas port. A_G Deg.	Inclination of air port. A_A Deg.	Resultant angle of A_A and A_G.	Resultant velocity of V_G and V_A M/S.	Min. temp. of immobile gas. Deg.	Drop of flame = Distance of tapping notch below port sill. Mm.
0·285	29·6	0·54	21·8	15	38	27	24·0	74	1150
0·358	23·5	0·57	20·6	13	40	29	21·2	58	980
0·440	18·9	0·72	16·3	33	33	33	17·3	22	980
0·260	32·4	0·56	21·0	10	38	25	24·5	70	1020
0·320	26·3	0·64	18·4	15	41	29	21·0	158	1370

TABLE II.

Capacity.	Length, ft.		Width, ft.		Area, sq. ft.		L/W.	
Tons.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
10	13·50	19·25	6·50	7·54	101·0	163·6	1·82	2·96
15	19·67	22·37	8·52	9·83	181·0	215·0	2·00	2·50
20	20·00	24·61	9·18	10·50	210·0	254·0	1·92	2·56
25	25·00	27·87	9·84	12·00	262·5	304·6	2·08	2·67
30	21·00	29·20	9·30	12·50	195·0	344·5	1·77	2·70
35	21·87	24·00	12·00	12·25	267·0	288·0	1·79	2·00
40	24·00	32·41	11·00	12·89	264·0	417·7	2·00	2·70
50	26·75	35·96	10·00	15·00	287·0	502·7	1·95	3·20
60	29·00	43·00	11·80	16·75	387·0	720·0	1·94	2·80
75	34·00	40·00	13·50	16·00	460·0	640·0	2·50	2·53
90	—	39·50	—	15·25	—	600·0	—	2·56

A. C.

56. The Necessity for Preheating Air in Furnace Work. A. POPOFF (*Sprechsaal*, 1921, **54**, 496).—In a glass tank furnace, the gases would leave the exit port at a temperature of, say, 1200°, and would enter the stack at 300°, an enormous fall in temperature, and the heat given up in this cooling should be imparted to the secondary air. A small tank furnace of 5000 kg. glass per twenty-four hours was considered, using 2500 kg. of oil (heat equivalent 10,500) of composition C, 85 per cent., H, 13 per cent., O, 2 per cent.

Thus 2500 kg. oil contained—

C = 2125 kg. needing for burning oxygen 8/3 × 2125 = 5667 kg.
H = 325 ,, ,, ,, ,, ,, 8 × 325 = 2600 ,,

8267 ,,
O = 50 ,, 50 ,,

Whence additional oxygen needed is 8217 ,,

and products of combustion are 11/8 × 2125 = 7792 kg. of CO_2.
9 × 325 = 2925 kg. of H_2O.
and 28835 kg. of inert N_2.

and the heat available from these in cooling 1200°—300° is—

for CO_2, 900 × 7792 × 0·222 = 1,556,842 calories.
for H_2O, 900 × 2925 × 0·466 = 1,226,745 ,,
for N_2, 900 × 28835 × 0·241 = 6,254,311 ,,

Total 9,037,898 ,,

While the heat given to the furnace by the burning of the oil was 2500 × 10500 = 26,250,000 calories, so that the amount regained by preheating should be in the neighbourhood of 29 per cent., that is, a saving of 857 kg. of oil. These figures were theoretical, and in practice only about half the saving could be obtained.

M. P.

57. Radiation Effects in Thermometry. Clark S. Robinson (*J. Ind. Eng. Chem.*, 1921, **13**, 820).—Instruments for measuring temperature, when placed in a gas, tended to approach the temperature of the gas. Hence the thermometer, etc., must either receive heat from the gas or lose heat, if the gas were at a lower temperature. This flow of heat to or from the thermometer occurred by conduction and convection between the gas and the thermometer, and by radiation between the thermometer and the surroundings. The rate of flow of heat by conduction from the gas to the thermometer could be expressed by the equation

$$\frac{Q}{\theta} = L_c A(T - t_\epsilon),$$

where $\frac{Q}{\theta}$ = heat flow per unit time.
L_c = coefficient of heat transfer by conduction expressed in suitable units, such as B.T.U. per °F. temperature difference between gas and thermometer per hour.
T = air temperature in °F. abs.
t_ϵ = thermometer temperature in °F abs.
A = area of surface thermometer through which heat is flowing.

The rate of flow of heat by radiation from the thermometer to the surrounding walls could be expressed by the equation (in English units)

$$\frac{Q}{\theta} = R_\epsilon \times 0{\cdot}162 \times A\left[\left(\frac{t_\epsilon}{100}\right)^4 - \left(\frac{t_\omega}{100}\right)^4\right],$$

where R_ϵ = black body coefficient of material from which the thermometer was made.
t_ω = temperature of surrounding walls in °F. abs.

Therefore, at equilibrium

$$L_c(T - t_\epsilon) = R_\epsilon \times 0{\cdot}162 \times \left[\left(\frac{t_\epsilon}{100}\right)^4 - \left(\frac{t_\omega}{100}\right)^4\right].$$

Hence if the values L_c, R_ϵ, and t_ω were known it was possible to calculate the true gas temperature T from the thermometer reading t_ϵ.

The heat transfer coefficient, L_c, could be calculated from the Beckett equation when the gas was moving under forced draft :

$$L_c = \frac{0{\cdot}44 V^{0\cdot8} T^{0\cdot5} C_p (m - 0{\cdot}081)}{M^{0\cdot1}(m - 0{\cdot}027)},$$

where L_c = B.T.U./hr./sq. ft. of heating surface/°F. difference.
V = lb. of gas/sq. ft. of cross-section of gas pass./sec.
T = temperature of gas in °F. abs.
C_p = specific heat of gas at constant pressure.
m = mean hydraulic radius of the gas passage in ft.
M = molecular weight of the gas.

When the flow of gas by a surface was due to convection currents only the value for L_c might be calculated from the formula (English units)

$$L_c = 0{\cdot}7 - \frac{\Delta_\epsilon}{375}\,.$$

Δ_ϵ was the difference in temperature between the hot walls and the thermometer, and must be calculated for each one separately.

The author included the following table for the black body coefficient (R_ϵ) for a number of substances :—

Substance.	R.	Substance.	R.
Absolute black body...	1·0	Gold, polished	0·05
Highly oxidised iron...	0·90	Silver, polished	0·03
Polished copper	0·07 to 0·10	Nickel, polished	0·35
Oxidised copper.........	0·70	Platinum	0·24
Bond metal	0·86	Glass	0·90

An optical pyrometer might be used to find the wall temperature, t_ω, when the walls were incandescent, and, for lower temperatures, a thermo-couple could be immersed in the wall surface.

Tests were also carried out to show the effect of various shields for thermometers. The following general conclusions were drawn : (1) For measuring gas temperatures thermometers must be corrected for the effect of radiation to the surroundings. (2) A silver shield would give fairly close approximations if uncorrected for measurements permitting small errors. (3) Bond metal should be substituted for silver if corrosive gases were present, and the readings should be corrected except for very approximate work. (4) Any thermometer would read practically the true temperature if the gas was moving at a very high velocity. Large deviations occurred only when the gas velocities were very low. (5) Thermometers would read true gas temperature exactly only when the surrounding walls were at the same temperature as the gas.

C. M. M.

VIII.—Chemical Analysis.

58. Quantitative Estimation of Arsenic, Antimony, and Tin. F. L. Hahn and P. Philippi (*Zeitsch. anorg. Chem.*, 1921, **116**, 201).—The sulphides were dissolved in the least possible amount of 10 per cent. sodium sulphide, and to the solution was added an equal volume of 20 per cent. caustic soda solution. After diluting to 50—100 c.c., hydrogen peroxide (10—30 per cent.) was added in small amounts with stirring, each addition producing a transitory bright yellow colour (if the liquid became permanently brown, more caustic soda was added). With large amounts of the elements present, the liquid became warm, and care had to be taken in the addition of the hydrogen peroxide. When the solution was quite colourless and commenced to evolve oxygen, sufficient of the oxidising agent had been added (during the operations sodium pyroantimonate might be precipitated). After boiling the solution for a short time it was cooled, a third of its volume of 80 per cent. alcohol was added, and after standing twenty-four hours the precipitated pyroantimonate was filtered off. Washing of the precipitate was carried out with increasing strengths of aqueous alcohol (first 1 water : 1 alcohol (80 per cent.), finally 1 water : 3 alcohol), to which a drop of caustic soda was added.

The precipitate was washed into the original beaker and dissolved with dilute hydrochloric acid containing tartaric acid, and reprecipitated as Sb_2S_3 in the usual way.

The solution from the pyroantimonate was collected in a porcelain or platinum dish, the alcohol driven off, and the solution diluted to 300 c.c. With stirring, as much 50 per cent. ammonium nitrate was run in as the amount of 20 per cent. caustic soda which had been originally added, causing precipitation of the tin as SnO_2. The liquid was boiled until ammonia was driven off, and the precipitate washed by decantation with dilute ammonium nitrate solution, ignited, and weighed as SnO_2. A. C.

59. A New Method of Estimating Silica. A. Travers (*Compt. rend.*, 1921, **173**, 714).—A method of estimating silica, even in presence of fluorine and alumina, was devised by the author, and accurate results were obtained without the lengthy process of evaporating down twice with hydrochloric acid.

The silica, converted into an alkali silicate, is then precipitated as silicofluoride, insoluble in a solution containing a sufficient concentration of potassium ions (15—20 gm. KCl in 100 c.c.). The precipitate, in suspension, is then titrated, boiling, with $N/5$-KOH solution free from carbonate, using phenolphthalein as indicator. This volumetric determination of the silicofluoride had been given by A. Hilemann (*Zeitsch. anorg. Chem.*, 1906, **51**, 159).

Working details of the method were as follows: The solution, say 50 c.c., of the alkali silicate was treated in a silver dish with at least 1 gm. of potassium fluoride for every 0·15 gm. of silica. Hydrochloric acid was then added so as to render the liquid just neutral, then a slight excess of acid, 2 c.c., was added, and finally an excess, 7—10 gm., of solid potassium chloride was added for every 50 c.c. of liquid. A sufficient concentration of KCl was necessary in order to make the precipitation of the potassium silicofluoride complete. This precipitate was filtered through a hardened filter, in an ebonite funnel, and washed with a 20 per cent. solution of potassium chloride until free from acid. The wet precipitate, suspended in boiling water, was then titrated as described above, using $N/5$-KOH.

Details were given for the application of the method to the determination of traces of silica in alkali hydroxides and salts, to the estimation of silica in presence of fluorine and alumina, and also to the analysis of silicates and quartz.

In the analysis of quartz or silicates, the sample was fused with caustic potash in a silver crucible, extracted with water, boiled, and filtered, so as to obtain the solution of the alkali silicate. If alumina were present, it was necessary to push the precipitate through into the filtrate, and neutralise with nitric acid, in place of hydrochloric acid, so as to avoid the formation of silver chloride.

When fluorine was present, two cases arose. (*a*) Alumina absent. Usual methods, modification more or less of Bergelius's method, involved an incomplete precipitation of silica, and further, if Zn were present, the precipitation of ZnO with the silica. The above method gave complete precipitation of the silica, and, further, when the fluorine was present in sufficient quantity, it was not necessary to add potassium fluoride. (*b*) Alumina present. Silica precipitated along with alumina, in presence of fluorine, retained some of the fluorine, and on evaporation with hydrochloric acid in the usual way, some of the silica was volatilised as SiF_4. Such a loss did not arise when using the method described by the author, hence this method was capable of wide application. Accurate blank determination of silica should be made on the materials used. V. D.

60. Perchloric Acid as a Dehydrating Agent in the Determination of Silica. H. H. Willard and W. E. Coke (*J. Amer. Chem. Soc.*, 1921, **42**, 2208).—The dihydrate of perchloric acid, $HClO_4,2H_2O$, having a boiling point of 203° acts as a very powerful dehydrating agent at this temperature. It has a great advantage over sulphuric acid, used for this purpose, in that most of its salts are soluble in the strong acid, and in water.

For estimating silica, the metal or silicate was dissolved in hydrochloric or nitric acid (where possible), adding perchloric acid, or dissolving directly in perchloric acid, evaporating until dense fumes were given off, then boiling gently for fifteen to twenty minutes to dehydrate the silica. The mixture was cooled, diluted with water, when the salts were easily dissolved, then the silica was filtered off. The silica was freer from impurities than was the case when evaporation to dryness with hydrochloric acid was employed, and the amount left in solution was negligible except for the most accurate work. The method, moreover, was rapid, and gave good results when applied to the analysis of high grade quartz sands, cements, limestones, Willemite, irons, steels, aluminium, and nickel. Treatment with the perchloric acid was preceded by the usual fusion with sodium carbonate in the case of the sands.

V. D.

61. A New Method of Estimating Fluorine in the Cold. Travers (*Compt. rend.*, 1921, **173**, 836).—This determination is the counterpart of that described in Abs. No. 59, for the estimation of silica. The fluorine was converted into alkali fluoride, and to this solution, generally alkaline, was added a known quantity of silica, as potassium silicate. Generally, twice the theoretical amount of silica necessary to convert the fluorine to potassium silicofluoride was quite sufficient. The liquid was then neutralised with hydrochloric acid, using as indicator methyl-orange, and a further excess, about 2 c.c., was added. Solid potassium chloride was added until its concentration in the liquid would be 20 per cent. The precipitated potassium silicofluoride was filtered, washed with a 20 per cent. solution of potassium chloride until free from acid, suspended in boiling water, and titrated with $N/5$-potassium hydroxide solution.

This method was found to give trustworthy results for the estimation of fluorine in soluble fluorides, calcium fluoride, and alkali fluoborates.

V. D.

62. A Rapid Process for Estimating Phosphoric Acid. H. Copaux (*Compt. rend.*, 1921, **173**, 656).—This method was based on the fact that, when in the presence of another acid, such as hydrochloric or sulphuric acid, the phosphoric acid was shaken with ether and an alkali molybdate, the phosphomolybdic acid thus formed united with the water and ether giving a dense yellow liquid which was non-miscible with water.

Into a specially constructed graduated tube 10 c.c. of the phosphate solution were run, then 10 c.c. of a 20 per cent. solution of sulphuric acid were added, followed by ether sufficient to form a layer 3 to 4 mm. deep. The mixture was shaken, then five or six portions of 15 c.c. each of a sodium molybdate solution were added, the mixture being well shaken after each addition. The sodium molybdate solution contained 100 gm. of molybdic anhydride per litre. The tube and contents were then agitated in a centrifuge, and in a few minutes the separation of the three liquid phases, excess of ether, the aqueous solution, and the yellow phosphomolybdic liquid, was complete. The volume of the dense yellow liquid was then read on the tube which had been calibrated beforehand by using a standard solution of a phosphate. Thus the percentage of phosphoric anhydride present in the solution under test could readily be determined.

Natural phosphates were treated with nitric acid for ten to fifteen minutes on a water-bath, evaporated to dryness if great accuracy were desired, then filtered, washed, and the filtrate made up to

100 c.c. The estimation of phosphate was then made on 10 c.c. of this liquid.

Citrates or citric acid interfered with the determination, and these had to be removed by evaporation and ignition. V. D.

IX.—Machinery for the Working of Glass.

63. Bottle-making Machine. E. S. Hutton, Lapel, Indiana (U.S.A. Pat., No. **1394092**, October 18th, 1921. Filed August 2nd, 1919, No. 314853).—In this machine a mould table, 30 (Fig. 18), is secured on a rotatable hollow column, 31, mounted on a stand, 32. Above an upper horizontal framework, 38, a driving wheel, 39, is secured to the upper end on the column, 31, and power from any suitable source is transmitted through this wheel to the machine. The mould table rotates continuously, and carries six or more sets of moulds. These moulds are mounted in a rotatable frame, 43, which is carried in bearings in the table, 30, and the moulds themselves are made in pairs so that each frame carries one blank, 41, and one blow mould, 42, located side by side, and each of them is formed in two halves, being divided along a plane that cuts both moulds as shown in Fig. 17. The outer halves of these compound moulds are fixed to blocks fitted in the rotating frames, whilst the other portions are fitted to blocks which slide between guides on the sides of the rotating frames. The blowing head, 52, has its inner end formed to constitute a neck mould, and also contains a cylinder, 57, in which the plunger, 58, is mounted. The inner sets of mould halves are moved from the fixed sets by a hollow tube which carries a roller at its inner end co-operating with a stationary cam. When the parison has been formed in the ordinary way the combined mould is given a half rotation by means of

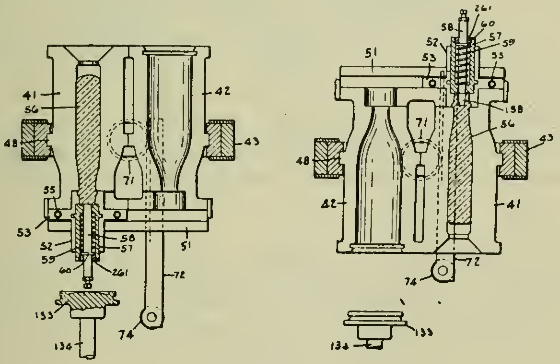

Fig. 17.

the rack, 72, to the position shown in Fig. 17 by the rotation of the framework in its bearings. At this stage the inner half of the mould is withdrawn, and the parison is carried by the neck ring over into the blow mould. The bottom block, 133, is forced upwards by a fixed cam, and the two halves of the moulds are again brought together ready for the blowing up of the bottle.

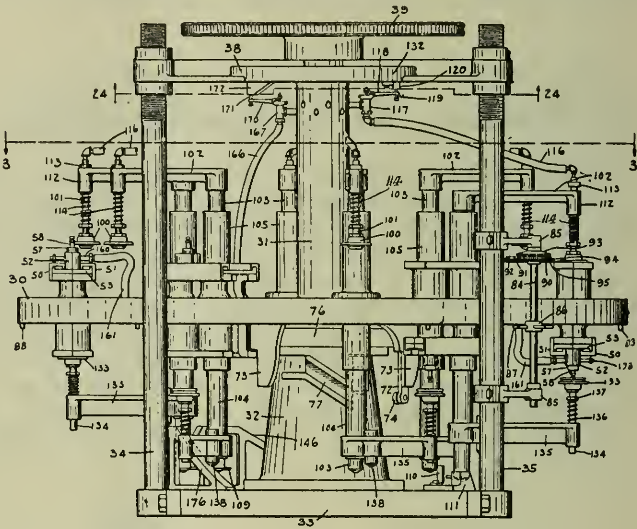

FIG. 18.

S. E.

64. Bottle-blowing Machine. M. MEUNIER, Rheims, France (Brit. Pat., No. **162193**, May 8th, 1920).—Relates to a machine for making hollow glass articles, particularly bottles, such as champagne bottles or syphons, which have to resist internal pressure, and is of the type in which the bottle during formation is carried by a table, rotating intermittently, to the mechanisms for performing the various operations of blowing. The machine comprises a horizontal table, 1, which is rotated step by step by means of a shaft, 27, Fig. 19, operated by a handle, 53, and is locked in operative positions by a detent, 24. The table carries six heads, 3, on which are mounted horizontal tubular shafts, 14, that are connected through valves, 10, to the main air supply. A turnover frame, 19, secured to each shaft, 14, carries a blowhead, 16, and a ring mould, 20. At the first station, the ring mould is upturned and is enclosed by one of a pair of parison moulds, 41, which are carried by a turnover frame mounted on a tubular shaft, 29. A charge of molten glass is dropped into the upturned parison mould and air is admitted above the metal through a cover, 42, which is brought down on to the mould, to pack the metal down into the ring mould. Both turnover frames are next rotated to bring the parison downwards, air being admitted to the blowhead, 16, to blow the parison slightly. The mould, 42, is then opened, and the table, 1, is turned to bring the parison to the next station. More air is admitted to elongate the parison, the bottom of which is supported by a member, 60, Fig. 20, which is raised and lowered by a pedal, 65. The shoulder of the parison is shaped by tools, 72, which are opened and closed by a hand lever, 67, and rotated by a hand-wheel, 68*a*. At the next station, the parison is brought to rest in a glory-hole, 75, where it is reheated and allowed to elongate, the amount of elongation being controlled by a member, 77, which is movable vertically by a hand-lever, 90. After heating, a mould, 76, is raised by a hand-lever, 88, and encloses the lower part of the parison, which is then given a first moulding.

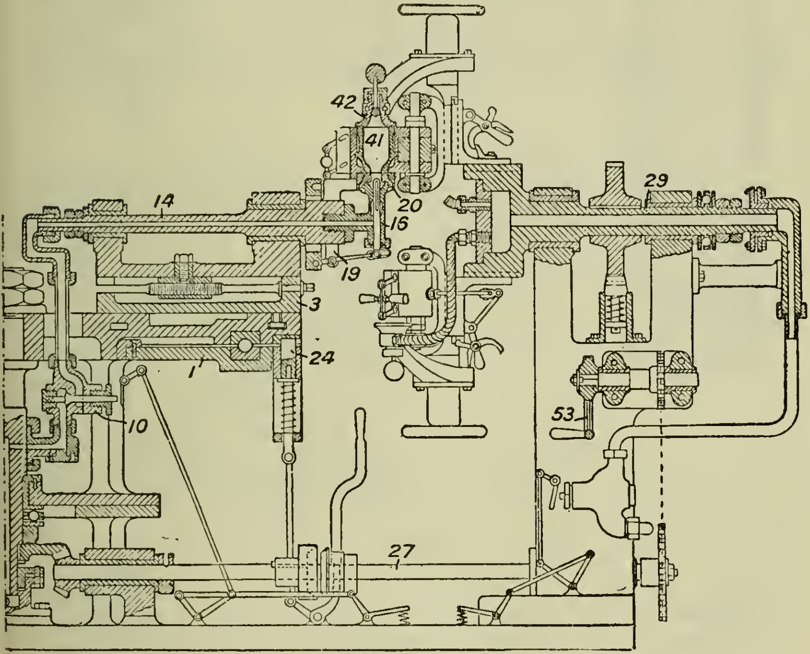

FIG. 19.

The glory-hole is heated by gas burners, the air supply of which is preheated by circulating through a recuperator, 81, surrounding the flue, 82. An inspection window is provided to enable the operator to watch the parison, and counterweighted doors are provided to close the inlet and exit of the glory-hole. The parison is next conveyed to a mould, 94, Fig. 20, which is raised into position by a counterbalanced lever, 104, operated by a hand-wheel,

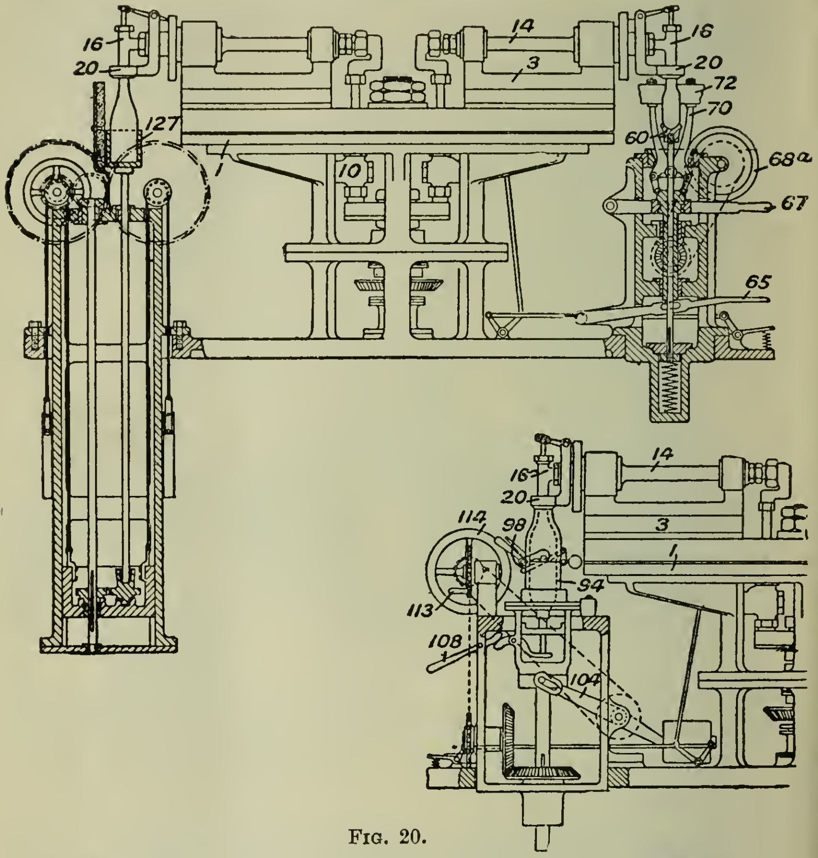

FIG. 20.

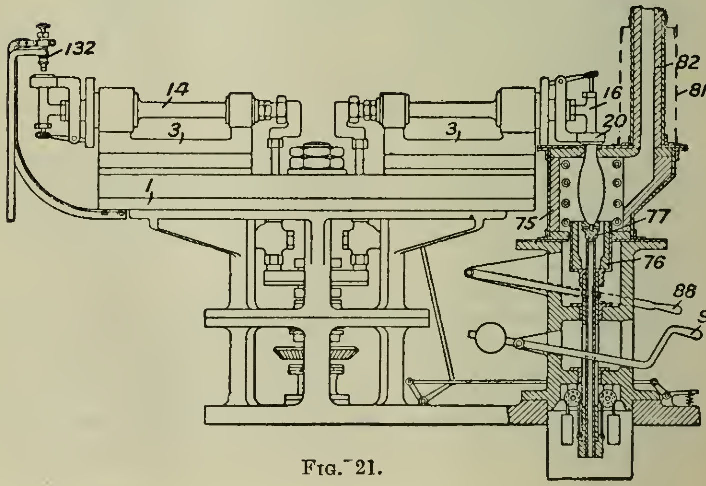

FIG. 21.

114, and is closed and locked by a lever, 98. The mould is rotated or oscillated during blowing by a handle, 113, and the "push" at the bottom of the bottle is formed by the mould bottom of conical shape, which is raised by a handle, 108. After the mould is opened and lowered, the table turns to the next station, where the bottle is released by opening the ring mould and is held in a receptacle, 127, which is raised into position. The receptacle is rotated in front of gas burners which reheat the bottle, and the completed bottle is then removed. The shaft, 14, is then turned to bring the ring mould upwards, and at the last station the ring mould is heated by a gas burner, 132, in order to bring it to a proper working temperature.

H. G. C.

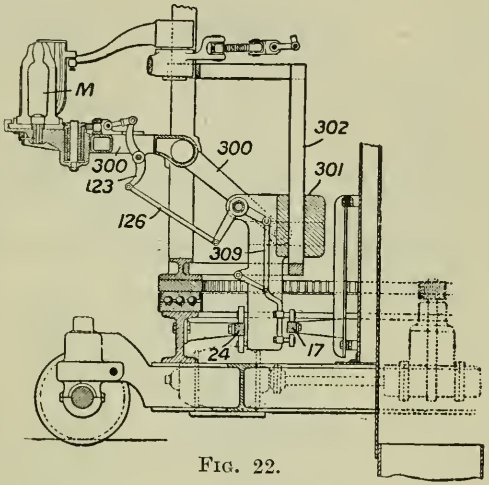

Fig. 22.

65. Automatic Bottle-blowing Machine. R. F. Hall, Moseley, Birmingham (Brit. Pat., No. **164675**, January 21st, 1918).—Relates to automatic bottle-blowing machines of the Owens type. According to the invention, the finishing-mould, *M*, is mounted on a lever, 300, of the first order provided with a balance weight, 301, which slides on a bar, 302. The lever, 300, is operated by a cam, 24, and the link mechanism, 123, 126, 309, which operates the mould halves, is actuated by a cam, 17. Electric solenoids or pneumatic pressure gear may be used in place of the cams for operating the machine. Specifications 164, 764, 165, 453, 165799, and 165800 are referred to.

Further patents on the same subject by the same inventor are :

(1) Brit. Pat., No. **164763**, July 10th, 1917.—This relates to a bottle-blowing machine of the Owens suction type, and consists in apparatus for operating the parison moulds and closely related parts. Fig. 23 shows the upper part of one arm of the machine. The frame, 47, carrying the parison mould, 52, etc., is hung on parallel levers, 36, 37, provided at their inner ends with a counterweight, 38. A fixed cam, 22, mounted on the central column, 16, engages a roller, 44, adjustably fixed to the weight, 38, and raises and lowers the parison mould, 52, to permit gathering, as the arm 28, rotates. The height of each parison mould can be varied independently by a hand-wheel, 35, which adjusts the height of a slide, 32, carrying the pivots, *P*, of the levers, 36, 37. The roller,

44, is correspondingly adjusted on the weight, 38. By this arrangement, moulds of different lengths can be simultaneously used in the same machine. The arms, 50, 53, which carry the parison mould halves, 52, are operated by link mechanism, 57, 58, 62, fitted with a roller, 63, engaging a tapered slot, 66, in a lever pivoted at 65 to the arm, 28, and furnished with a roller, 67, engaging the operating-cam, 21. The neck rod, 71, is withdrawn by a screw, *S*, which is turned at the correct time by a square telescopic shaft, 72, operated through rods, 78, 79, by a central cam, 81. Toggles for opening the neck mould, *M*, are similarly operated by a telescopic shaft, 87, and cam, 82. In a modification, the weight, 38, is moved by an electric solenoid instead of by the cam, 22, and the parison mould is opened by solenoids instead of by the cam, 21. The parison mould mechanism described above, and also the corresponding finishing-mould mechanism, are carried by a double column, *C*, which is secured at the top to the arm, 28, and at the bottom to a rotating ring mounted on a ball bearing. By this means a complete set of moulds, etc., can be removed from the machine as a single unit for repair and replaced by a fresh unit. Specifications 164763, 165799, and 165800 are referred to.

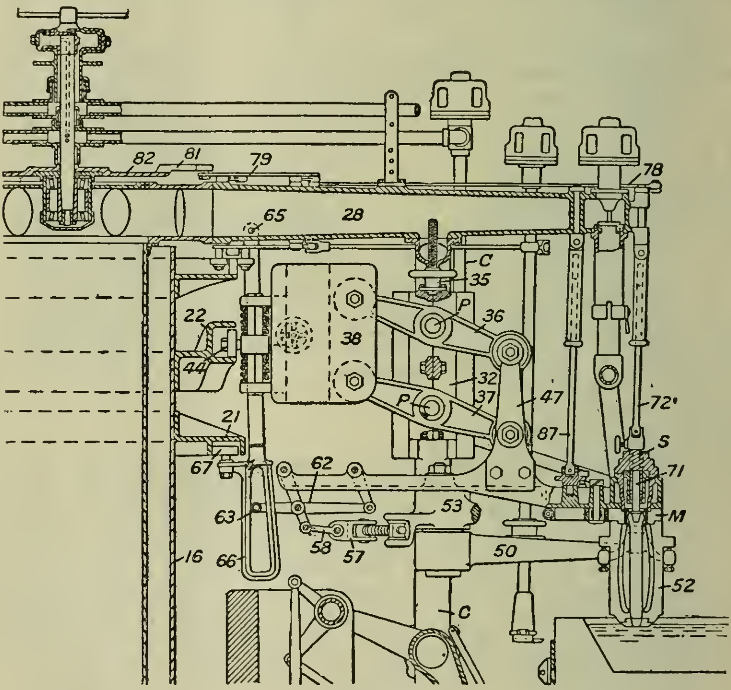

Fig. 23.

(2) Brit Pat., No. **164764**, September 19th, 1917.—This relates to bottle-blowing machines of the Owens type. According to the invention, each set of parison forming and blowing mechanisms is arranged as a single unit which can be readily removed from the machine for repair or replacement. Each unit consists of a loop-shaped frame, *L*, secured at its lower end to a ball-bearing ring, 15, and carrying within it the parison and finishing mould-operating mechanisms, *P*, *M*. The top of the loop frame, *L*, is secured to a hollow radial arm, 28, which is bolted to a central chamber, 26. By this arrangement, the arm, 28, and the bottom of the frame, *L*, can be detached from the chamber, 26, and ring, 15, respectively, and the whole unit may then be removed for repair, etc. The opening left in the chamber, 26, must be closed, if the unit removed is not replaced by a fresh one. Specification 165800 is referred to.

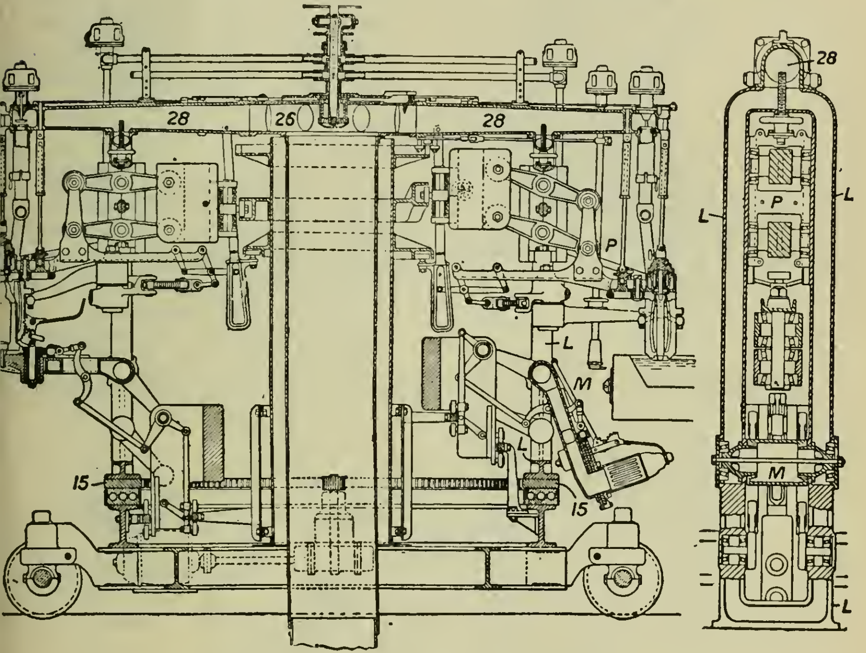

FIG. 24.

(3) Brit. Pat., No. **165112**, July 10th, 1917.—According to the invention, the knife, 109, is mounted on a tubular shaft, 100, which rotates in an upper bearing, 103, fixed to one of the radial arms, 28, of the main frame, and a lower bearing, 101, fixed to the lever, 50, which supports one half of the parison mould, *M*. The bearings, 101, 103, are of the universal type so as to permit lateral movement when the parison mould is opened. The shaft,

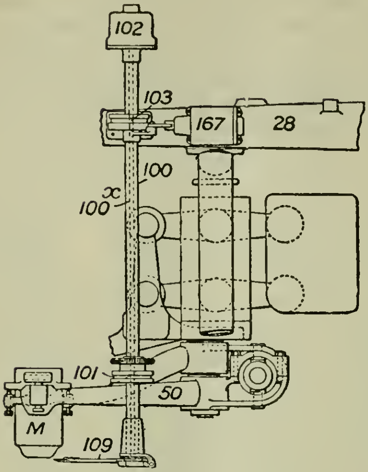

FIG. 25.

100, may be rotated either by cam mechanism or by an electric solenoid, 167. After the cut has been effected, the knife, 109, may be pushed down clear of the bottom of the parison mould by a rod, 100x, passing through the shaft, 100, and worked by a solenoid, 102. Specifications 165800 and 164763 are referred to.

(4) Brit. Pat., No. **165453**, July 10th, 1917.—This relates particularly to the blowing moulds and apparatus for the delivery of the finished bottle. Figs. 26 and 27, taken together, show one arm of the machine. The blowing-mould halves, *M*, are mounted on a hollow lever, 110, swinging on a hollow trunnion, 31, and balanced by a weight, 113, which is raised and lowered at the required times by a fixed cam, 24, fluid pressure mechanism or

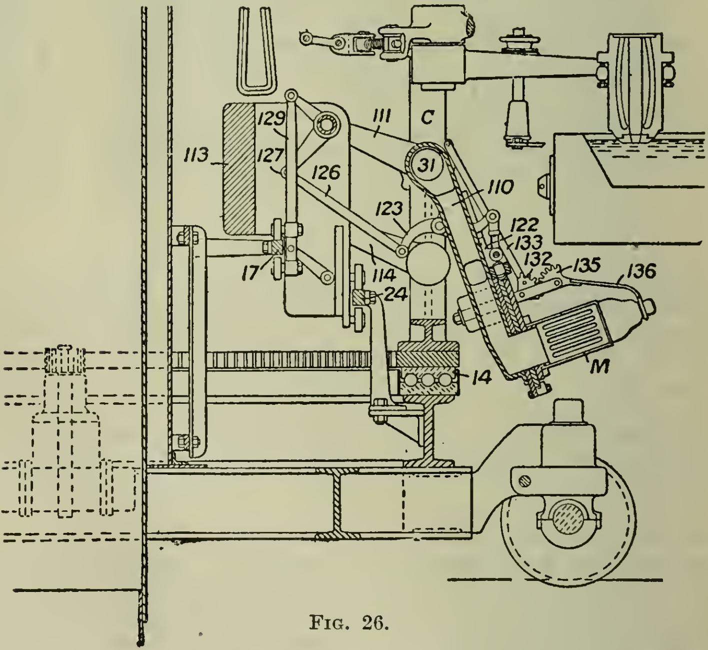

FIG. 26.

an electric solenoid. A link, 114, pivoted to the weight, 113, forms a parallel motion with the end, 111, of the lever, 110. The mould, *M*, is opened and closed by a cam, 17, acting through links, etc., 122, 123, 126, 127, and 129. A fork, 136, is brought down by the action of toothed quadrants, 132, 135, and a link, 133, on to the bottle neck to prevent the bottle from sticking to either mould half when the mould opens to discharge the finished bottle. The mechanism described above is mounted on a loop-shaped column, *C*, connecting the arm, 28, with the ball-bearing ring, 14. The valves controlling the blowing air and suction are operated by electric solenoids, 149. Specification 165800 is referred to.

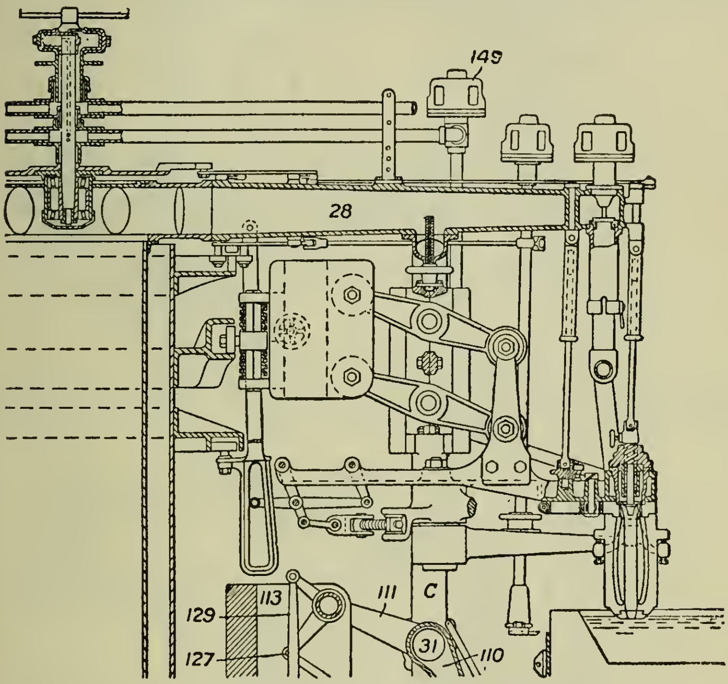

FIG. 27.

(5) Brit. Pat., No. **165799**, January 21st, 1918.—In a glass-blowing machine of the Owens type in which each parison mould, *P*, is raised and lowered vertically and is separately counter-balanced by a weight, 214, acting through bell-crank levers, 203, 211, and rods, 204, 208, 212, the mechanism is operated by a pneumatic cylinder or electric solenoid, 207, or by a vertical cam or by a combination of these. An electrically-operated lock may be provided to hold the parison mould, etc., in the raised position,

and dash-pots may be used to reduce shock. Specifications 164763, 164764, 165453, and 165800 are referred to.

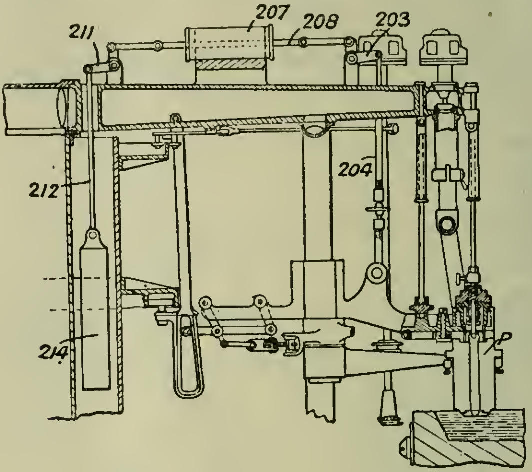

Fig. 28.

(6) Brit. Pat., No. **165800**, July 10th, 1917.—This relates to an automatic glass-blowing machine of the Owens type. The present invention relates to the frame of the machine and to cooling the moulds. Figs. 29 and 30, taken together, show one arm of the

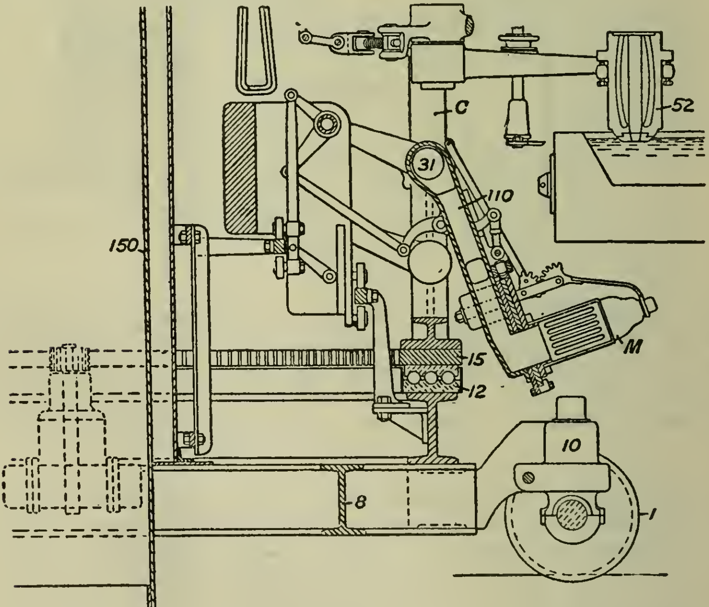

Fig. 29.

machine. The underframe, 8, is mounted on four wheels, 1, and its height can be adjusted by screws in casings, 10, which can be worked simultaneously by one handle. A ball-bearing ring, 12, is supported at three points on the frame, 8. The upper member, 15, of the ball bearing carries hollow columns, *C*, supporting hollow arms, 28, which are bolted to a central chamber, 26. The arm, 28, column, *C*, and apparatus carried by them constitute a complete bottle-forming unit, and can be removed from the machine without interfering with the other units. Cooling air passes from a fan, etc., up a central trunk, 150, through the chamber, 26, along the arm, 28, down the column, *C*, through a hollow trunnion, 31, to the finishing-mould carrier, 110, from slots in which it issues to the finishing-mould, *M*. The parison mould, 52, is cooled by air which passes from the arm, 28, through an electrically-operated valve, 153, and down tubes, 96, 98. The valve, 153, is closed while the parison mould is over the tank to avoid cooling the molten metal. H. G. C.

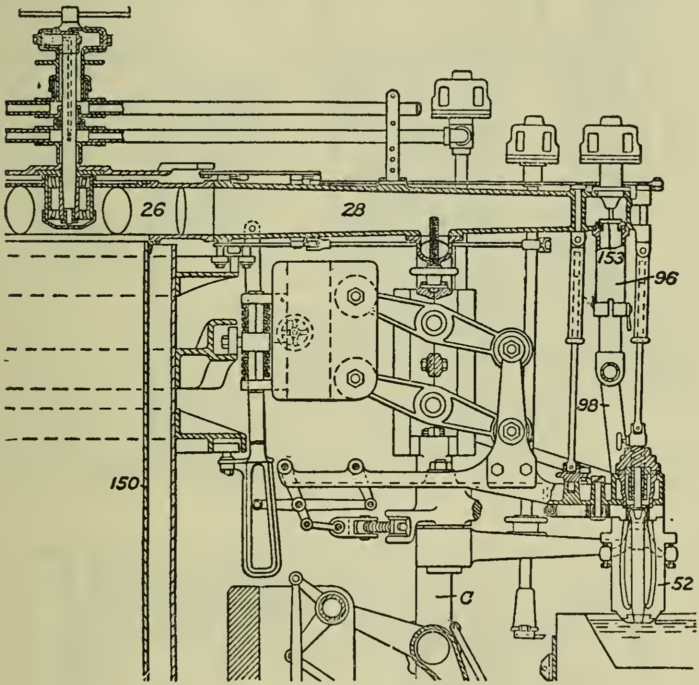

FIG. 30.

66. Improvements in Automatic Glass Bottle Machinery. T. C. MOORSHEAD, London (Brit. Pat., No. **165875**. October 8th, 1919).—Relates to a glass bottle, etc., making machine of the automatic continuously-rotating frame type. The parts are operated by cams, mounted on a central column, 7, Fig. 31, in the usual way, except the plunger, 158, which is pneumatically operated as shown. According to the invention, the molten model flows continuously from a hole, 5, in a tank, 4, through a fixed ring, 63, into each parison mould, 60, as it arrives in the filling position.

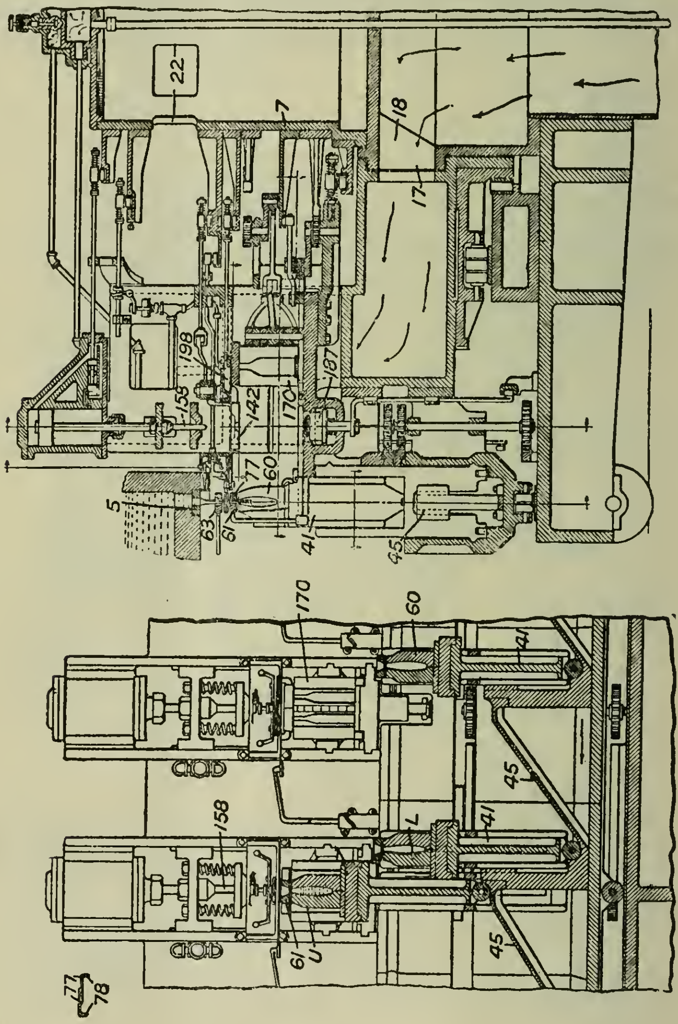

FIG. 31.

Each parison mould, 60, is mounted on a carriage, 41, which is moved by gearing along an inclined track, 45, extending over a small arc of the main frame. This movement takes place at the filling point and is timed so that when the mould reaches the filling point the carriage, 41, commences to move along the track, 45.

The result is that the mould remains below the hole, 5, and rises to meet the falling stream of glass. By the time the mould has reached the upper position, *U*, Fig. 31, the next mould has arrived at the position *L*, close to it. At this moment shears, 77, cut the stream of molten glass and the movement of the main frame carries the upper mould, *U*, from under the hole, 5, and brings the lower mould, *L*, below it, before the falling stream reaches the lower level. The lower mould then rises vertically until its carriage, 41, reaches the end of its track, 45, when the mould is carried forward again. Before reaching the filling point again each carriage, 41, is moved to the bottom of its track, 45. In this way, each parison mould is kept moving continuously, either rotating with the main frame or rising vertically during the filling operation. Each parison mould is provided with a guide, 61, and the shears, 77, are formed with depending flanges, 78, Fig. 31, to prevent lateral splashing of the molten metal at the moment of cut-off. When charged, the parison mould, 60, is withdrawn below the plunger, 158, which descends through the neck mould, 142. The blowing-head, 198, is moved forward when the plunger, 158, rises and air is introduced into the parison. The parison mould, 60, is then opened and the finishing-mould, 170, and bottom, 187, moved into place. On the completion of the blowing, the finishing mould is moved radially outwards over the parison mould, which is then in the lower position. The mould is opened and the finished article removed by rotating grippers, which place it on a conveyer, etc. Cooling-air passes through ports, 17, 18, as shown by the arrows. Access may be had to the cams, etc., for adjustment from the central column, 7, through holes, 22. H. G. C.

67. Mechanism for Forming Bottles with Re-entrant Bottom. R. La France, Toledo, Ohio, Assignor to Owens Bottle Co., Toledo, Ohio (U.S.A. Pat., No. **1404206**, January 24th, 1922. Filed June 12th, 1919, No. 303544).—This invention relates to mechanism for forming bottles or similar articles of glass, and more particularly to means for forming bottles having a re-entrant portion at the bottom. The mechanism is adapted for use with an automatic bottle-blowing machine of the Graham type. As each blank mould, 15, is brought to the charging station, a charge of glass is introduced and forced downwards so that a portion of the glass enters the ring mould, 25, thus forming the neck of the bottle. A head, 26, is then brought down on top of the blank mould, the plunger, 27, is withdrawn, and air under pressure is admitted to blow up the parison. The under side of the head, 26, is shaped so as to form to a certain extent the bottom of the bottle, and for this purpose it is provided with a central projection, 28, surrounded by an annular space into which the glass is forced by compressed air. After the parison is thus formed, the blank mould sections are separated, leaving the bare blank supported by and projecting upward from the neck-ring mould. The blowing head, 30, which carries the neck mould is inverted by the rack, 31, and pinion, 32, on the axis of the head, 30. The bare parison is thus swung to a position between the open sections of the blow mould as shown in Fig. 33. On closing these blow-mould sections surround the mould bottom, 33, which contains a vertically movable central section, 34, which is moved downwards by the spring, 35, and upwards by the cam, 36, on the frame, 10. This movable section, 34, is moved upwards after the mould closes and its projection enters the space formed in the parison by the projection, 28. The cam, 36, is long enough to hold the movable section up until the bottle has been blown and the glass has hardened sufficiently to retain its shape. When this section, 34, is withdrawn, the mould sections are opened and the base, 33, is tilted about an axis, 37, by the action of a stationary cam, thus ejecting the bottle. S. E.

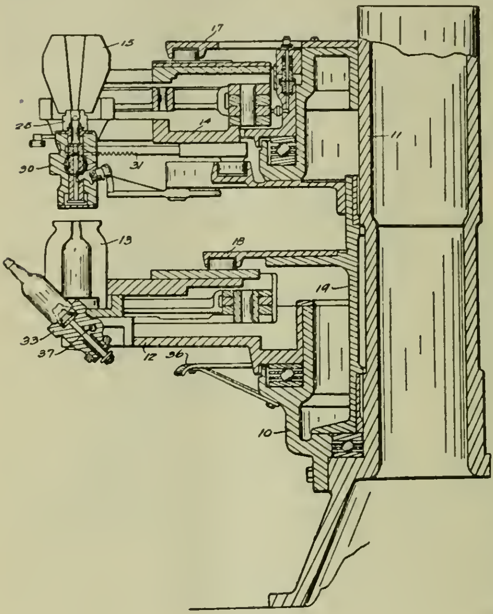

Fig. 32.

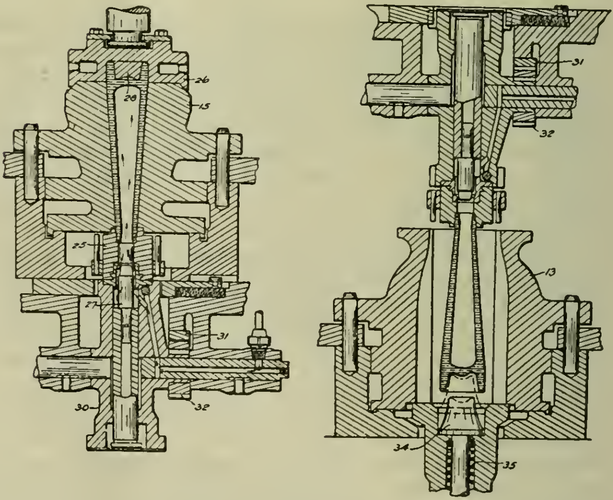

Fig. 33.

68. Improved Semi-automatic Bottle Machine. E. Hughes, London, J. Middleton, Leeds, and B. Wilson, London, and Glassworks, Ltd., Edmonton, London (Brit. Pat., No. **162029**, December 19th, 1919).—Relates to bottle- and like blowing-machines of the type in which one or more turnover heads, *c*, are carried by a head, *b*, adapted to rotate about a vertical axis. According to the invention, the machine is arranged so that the molten metal is drawn down into the neck mould, *e*, by suction, the plug, *f*, is withdrawn, and a puff of air is introduced whilst the turnover head, *c*, is stationary. Suction is applied through a pipe, *s*, taps, *t*, and a spring boss, *u*. Compressed air is admitted through a pipe, *w*, *z*, and spring valve, 1, operated by a handle, 3, on the opposite side of the machine. The pipe, *p*, is common to both suction and compressed air. The levers, *l*, *m*, for operating the plug, *f*, may be worked from a treadle, *o*, on the opposite side of the machine. For making screw-necked bottles, gear is provided for rotating the plug, *f*, as it is withdrawn. H. G. C.

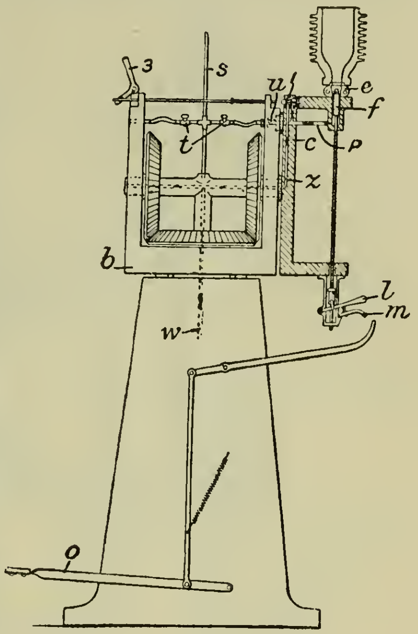

Fig. 34.

69. Automatic Glass-blowing Machine. E. Lecoultre, Paris, France, Assignor to Compagnie Général d'Electricité, Paris (U.S.A. Pat., No. **1401713**, December 27th, 1921. Filed December 27th, 1919, No. 347836).—The subject of the present invention is an entirely automatic machine which effects all the operations ordinarily executed manually by glass blowers. The main body of the machine comprises two cylindrical castings bolted together, the upper casting, 9, merging into a large circular plate having two concentric tracks, 41 and 41′, which serve to guide radial arms mounted for pivotal movement around the axis common to the two cylinders. The two main shafts, 10 and 11, are operatively connected by gearing, 12, the ratio of which is the same as the number of arms on the machine.

The tracks, 41 and 41′, normally determine the position of the blow tube, 36, but in front of the furnace a deep notch is cut in these tracks, and in this notch rests the end of the lever, 46, so that this lever now acts temporarily as the blow pipe support. Through intermediary links, etc., this lever, 46, is actuated by a cam, 49, on the shaft, 11, and by this means the end of the tube is lowered into the glass and later withdrawn, the gathering iron

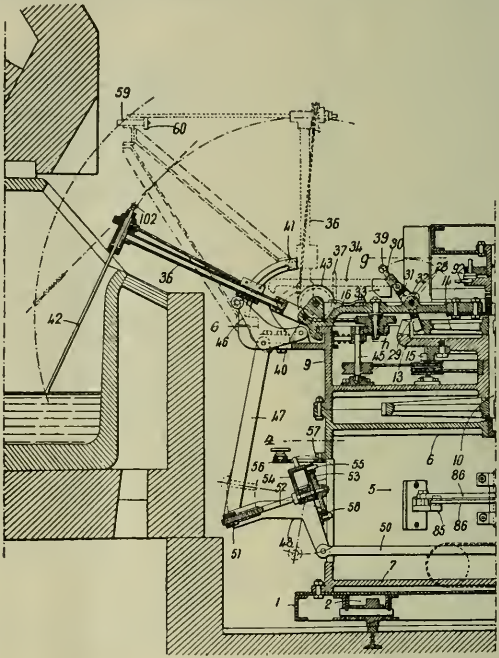

FIG. 35.

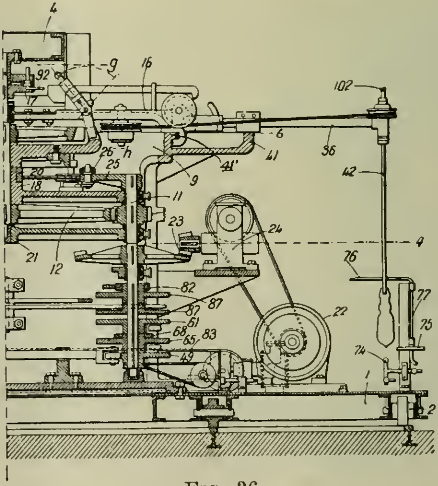

FIG. 36.

being brought back to the horizontal position. The next movement of the main frame of the machine brings the gathered glass over a marvering plate over which the glass is rolled, the rotation of the gathering iron being derived from the belt, 46′. The marvering being complete, the blowing iron is quickly brought to the vertical and elongation of the glass is obtained by swinging the iron about a vertical position by means of a sinuous contour in the track, 41. The blowing mould is then brought into position below the blowing iron and closed round the glass by means of cams, and at the same time a third cam acting through a lever opens a cock which supplies air to blow the glass up to shape.

The finished article may be cut off by rotating it in front of a cutting or chilling device. A cam also may liberate a lever and allow it to strike against the blowing iron, thus effecting the breaking off.

The glass remaining on the blowing iron is removed in the next position by means of jaws which open and close abruptly on the end of the blowing tube with a frequency dependent on the contour of the cams, 87. S. E.

70. Conveyer for Bottles. A. J. H. Haddan, London, and the Owens Bottle Co., Toledo, O., U.S.A. (Brit. Pat., No. **165350**, August 5th, 1920).—Relates to apparatus for transferring bottles or other articles and is described as applied to the transfer of bottles from a blowing-machine to the annealing-lehr. The bottle, 5, is discharged from the blow mould, 6, head first down a shoot, 7, from which it jumps on to a shoot, 18, which delivers it in an upright position on to a conveyer, 13. A pivoted spring plate, 24, and a spring buffer plate, 26, are provided to assist in placing the bottle, 5, without shock on the conveyer, 13. H. G. C.

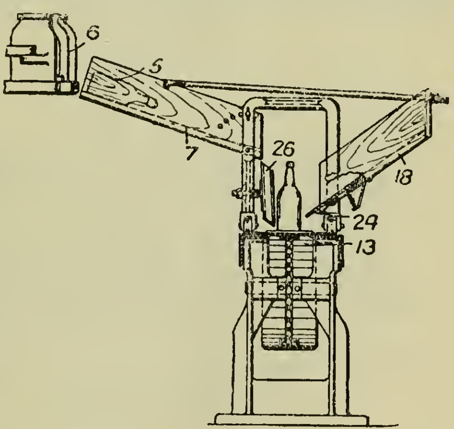

Fig. 37.

71. A New Type of Press and Blow Machine. R. F. Hall, Birmingham, England (Brit. Pat., No. **164365**, January 23rd, 1918; U.S.A. Pat., No. **1393118**, October 11th, 1921. Filed January 15th, 1919, No. 271223).—Instead of mounting parison and blow moulds on tables, as in ordinary practice, they are mounted in this machine on a continuously rotating conveyer. The links of this conveyer consist of plates or platforms on which the parison and blow moulds are mounted. Above this conveyer is another similar conveyer rotating at the same speed but in the opposite direction. The plates of this second conveyer carry the plungers, blowing means, and other such associated parts for operating on the glass. The conveyers are arranged so that the lower side of the top conveyer during a portion of its course travels in the same direction and in close proximity to the upper side of the lower conveyer, thus the moulds are brought into contact for a definite period with the glass-forming means. Suitable guides and supports are provided to prevent any sagging of the horizontal platforms and to resist any pressure that may be imposed on them during the shaping of the glass. On the side frames are fixed guides or projections which act as cams to operate levers, raise or depress plungers, open or close moulds, apply and remove blowing covers, and effect any other operations which can be effected as the moving platforms pass fixed guides or cams. As the moulds mount the rollers at one end of the track gobs of glass are fed into them, and then as they pass along the horizontal track the various pressing and blowing operations are accomplished. On reaching the end of the horizontal track the glass is completely shaped and in turning over the end roller the mould is automatically opened and the finished article discharged. S. E.

72. Machine for Making Pressed Glassware. T. C. Moorshead, London (Brit. Pat., No. **166272**, October 6th, 1919).—Relates to a multiple automatic machine for the manufacture of

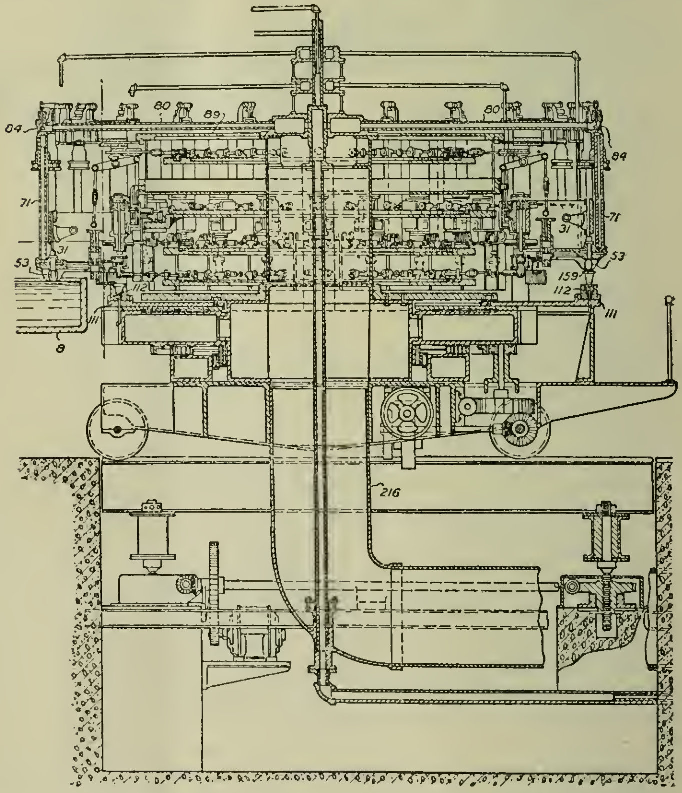

Fig. 38.

pressed glassware. The main aim of the invention is the gathering and placing of the charge in the mould in an unchilled state. The moulds, 112, are mounted on a continuously rotating frame and a suction gathering-device, 58, is provided for each mould. The

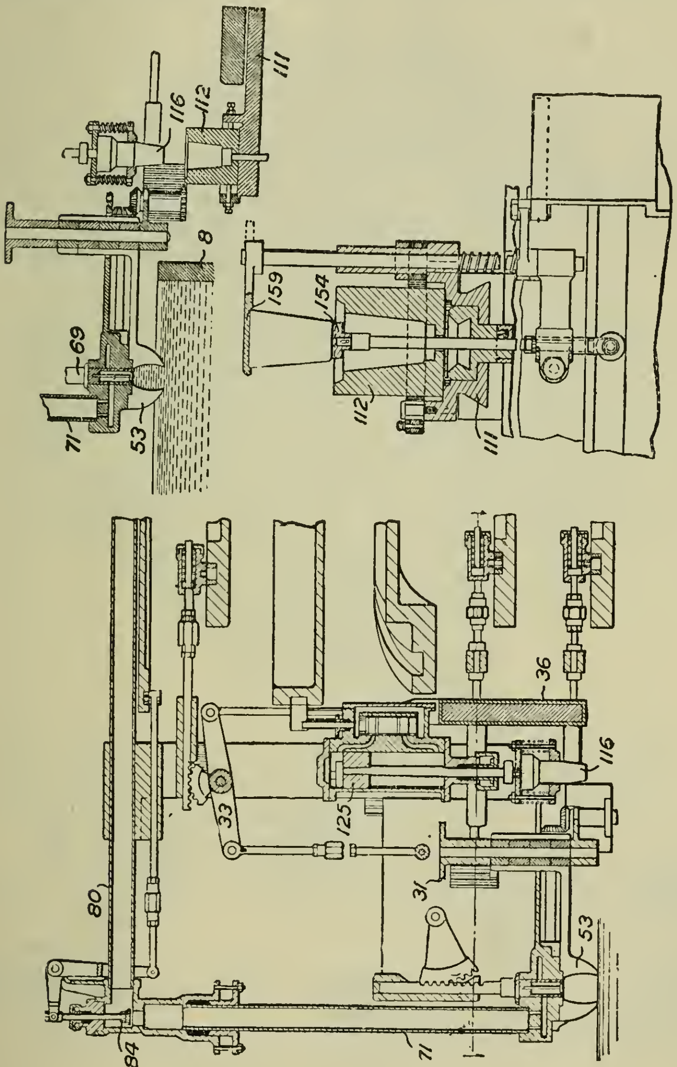

Fig. 39.

metal is pressed by a plunger, 116, in the usual way, and the finished article is removed by a rotary apparatus, *R*. The parts are operated by cams, in the well-known way, except the plunger, which is pneumatically operated. The gathering-device consists of a two-part cup, 53, mounted on a frame, 31, suspended from a lever, 33, and balanced by a weight, 36, Fig. 39. The air is exhausted from the cup, 53, through a tubular valve, 69, pipe, 71, valve, 84, and pipe, 80. When the cup, 53, is full it is raised and

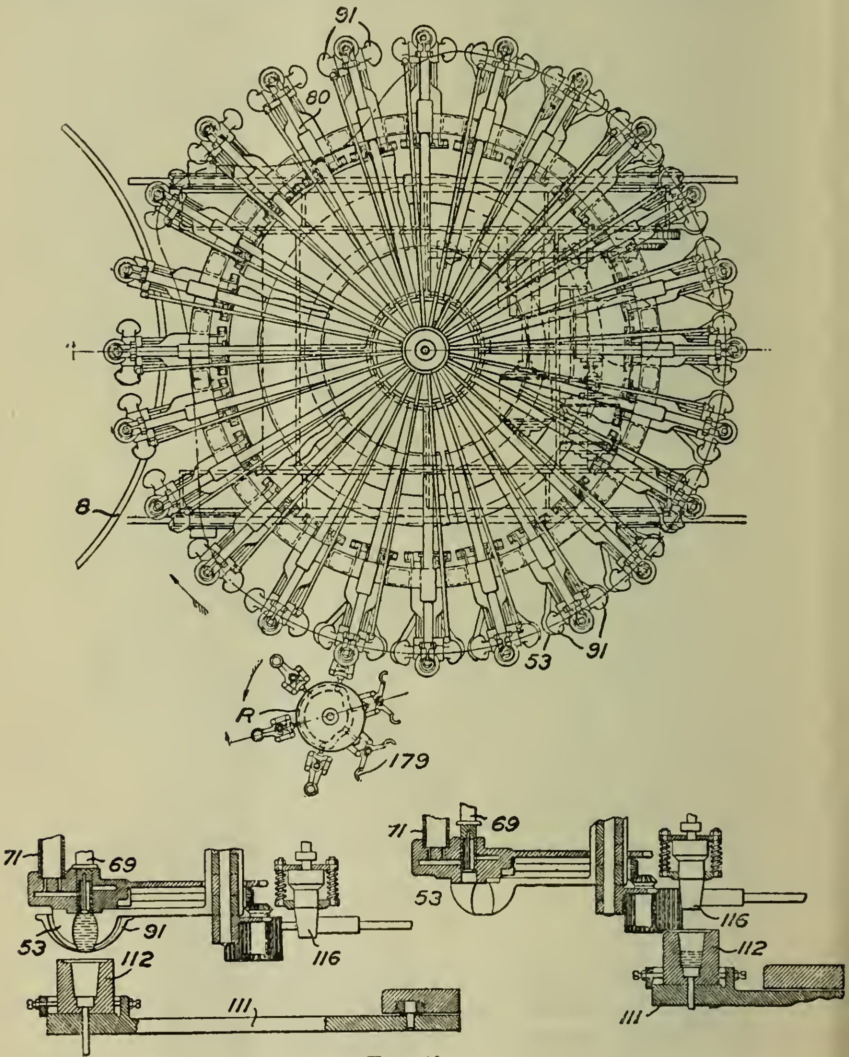

FIG. 40.

the vacuum cut off by the valve, 69. The valve, 84, is also closed to prevent leakage during the remainder of the cycle of operations. The bottom of the cup, 53, is closed and the excess of metal cut off by knives, 91, of spherical form. By this time the cup, 53, is clear of the tank, 8, and the mould, 112, is projected radially beneath the cup, 53, on a slide, 111. The knives, 91, are withdrawn, the cup, 53, is opened and compressed air is admitted to it to expel the charge into the mould, 112, which is then retracted beneath the plunger, 116. The ware is then pressed by the pneumatic apparatus, 125, and subsequently ejected by a movable bottom, 154. It is steadied by a recessed plate, 159, until seized and removed by rotary grippers, 179, and placed on a conveyer, etc. In the case of the finished article having a design on the surface which would interfere with satisfactory ejection, the mould is made in four segments which are opened radially prior to the rise of the bottom, 154, thus freeing the design from engagement with the mould. The position of the machine relative to the tank, 8, can be adjusted by the gear shown in Fig. 38. Cooling-air enters by a central trunk, 216. H. G. C.

73. Machine for Making Glass Marbles, etc. G. J. THOMPSON, Clarksburg, West Virginia, Assignor to GLAMAR MACHINE CO., West Virginia (U.S.A. Pat., No. **1374966**, April 19th, 1921. Filed August 25th, 1919, No. 319551).—The invention relates to machines for making spherical articles such as balls, marbles, or casters from molten glass, the shaping being done while the mass of glass is still pliable, and continued during the time the articles are cooling, so that when they are delivered from the machine they retain the desired shape. The machine consists essentially of a turntable (Fig. 41) with a plurality of shaping channels, 7, substantially half round in section, starting near the centre and ending near the circumference of the table. Above the table are mounted shaping rolls, 8, having spiral shaping channels, 9, which correspond in cross-section with channels on the table. These rolls are geared with the table by the toothed wheels, 11, 13, and 14, so that as the table rotates so do the rolls and at such a speed that the channels 9 are always kept in register with the table channels.

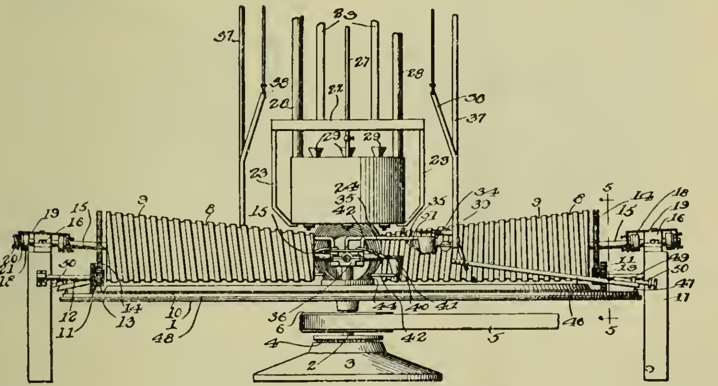

FIG. 41.

Mounted over the centre of the table is a heated chamber, 24, which contains a pot holding molten glass. By an ordinary timing and shearing device, this glass is delivered in suitable sized gobs through a funnel or chute in turn to each of the channels on the table. By the rotation of the table and the action of the rollers forcing this glass along the channel, it assumes a spherical shape and rolls on towards the circumference of the table, where the channels end in discharge openings. S. E.

74. Glass Gathering Mechanism. A. Kadow, Toledo, Ohio, Assignor to Westlake Machine Co., Toledo (U.S.A. Pat., No. **1350552**, August 24th, 1920. Filed May 25th, 1917, No. 170895).—This gathering device comprises a mould, 27, with hinged sections, 18, formed with semicircular recesses, 14, on their inner faces. When these mould sections are closed glass may be drawn into them by suction from the body of molten glass, 31. The body portion, 17, of the mould is mounted on an angular shank, 20, the end of which is fixed in the revolvable sleeve, 21. This sleeve is revolved on its axis, 180, first in one direction and then in the other by means of spiral slots, each passing one-half way round the circumference of the sleeve, into which fit rollers carried on studs secured to slides. These slides are reciprocated by means of a groove on the under side of the cam, 11, thus dipping the mould into the glass and then inverting it to the position shown. The upward movement of the gathering mould causes the gathering end of the mould to pass by a knife, thus shearing off any glass that may have adhered to the mould. When in this discharging position the neck-mould sections are opened and the gathering iron, 14, is depressed and the glass is gripped in between the jaws, 15, ready for further manipulation. S. E.

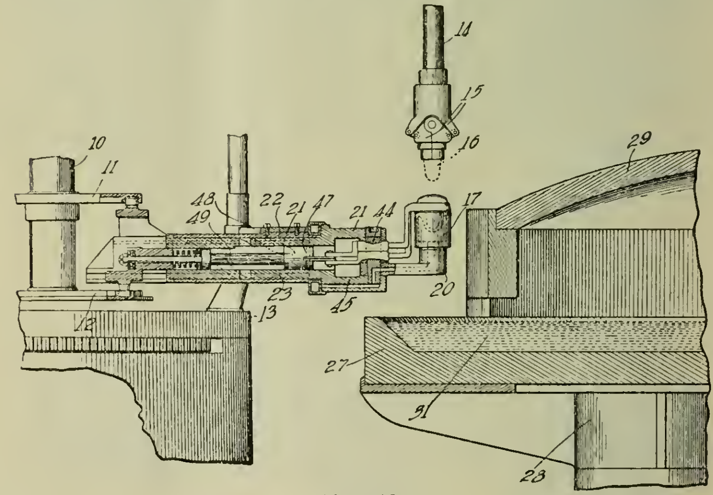

Fig. 42.

75. Glass Gathering and Shaping Machine. M. J. OWENS, Toledo, Ohio, Assignor to TOLEDO GLASS Co. (U.S.A. Pat., No. **1364514**, January 4th, 1921. Filed April 18th, 1912, No. 691589).—This machine is designed to gather a definite quantity of glass and form it into a desired shape by pressing in a mould. It is intended that a series of these units or arms should be mounted on a rotating frame as in the Owens bottle machine. By this rotatory movement the section head is brought over the molten glass in the tank, 57 (Fig. 43), and during the period in which it is passing over the glass it is lowered so that the gathering cup, 31, is brought close down to or in contact with the glass surface. At this point the valve, 70, is opened, and a vacuum produced in the gathering cup, which causes the glass to flow into and fill the cup. On passing further round the gathering head is rocked so as to clear the edge of the pot, and at the same time it passes over the knife, 40, which cuts off any trailing glass. When clear of the tank the gathering head is rocked about its pivot by the sliding bar, 35, co-operating with the fixed camway, 37. When at the limit of its motion, as shown by the dotted lines, the gathering cup is immediately above the press mould (shown in dotted lines). Towards the end of the rocking motion the roller, 24, which is fixed on the end of a rod connected to the sleeve, 21, runs on to the fixed cam, 34, and thus causes the two halves of the gathering cup to open and allow the glass to fall into the mould beneath. The gathering head is then rocked back to the vertical, and by the opening of a valve air is admitted to the cylinder, 64, thus forcing the piston and the plunger, 61, downwards. After the plunger has pressed the article to the desired form, air is admitted to the other end of the cylinder and the plunger is thus withdrawn. By the co-operation of a cam and

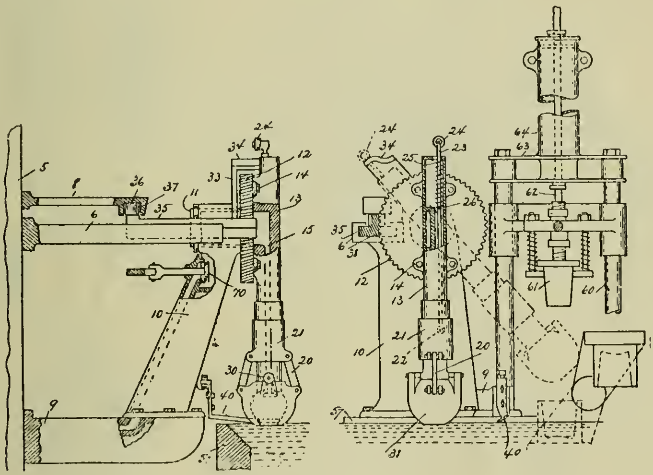

FIG. 43.

rack bar, the mould is then inverted to the position shown in Fig. 26 in full lines, thus discharging the pressed article, and at the same time raising the mould to a position above the level of the glass tank, 57, during the gathering operation. S. E.

76. Glass-feeding Device. F. O'Neill, Toledo, O. U.S.A. (Brit. Pat., No. **166605**, January 28th, 1920).—According to the invention, molten glass flows continually in a stream, 28, from a furnace extension, 12, and is cut off into charges by shears, 27. The charges drop into the mouth of a fixed funnel, 34, which makes close contact with the parison moulds, 53, and are drawn down into the neck moulds by suction applied through a hollow piston-rod, 72, and passages, 75, 83, in the plungers, 73, and parison moulds, 53, respectively. The funnel, 34, is provided with gas burners, 37, to heat the incoming charge, with oil-holes, 44, to lubricate it and with water or steam cooling channels, 47, to prevent excessive heating of the lower part. H. G. C.

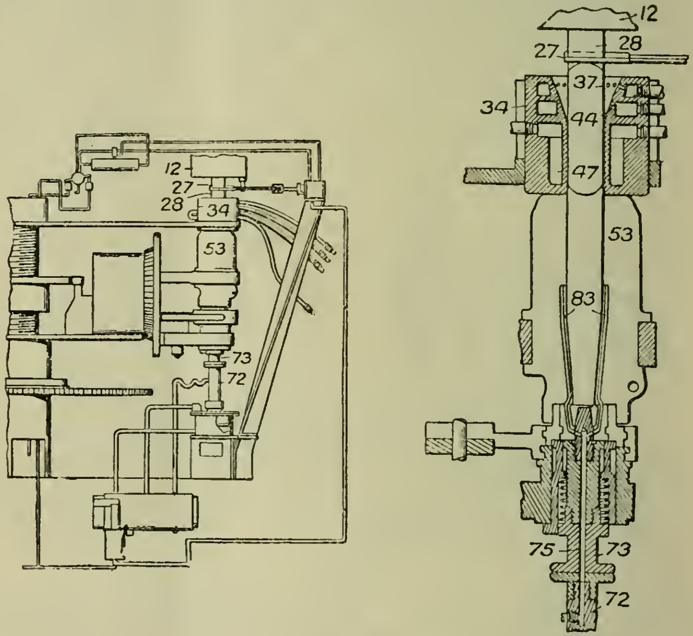

Fig. 44.

77. Water-cooling Device in Drawing Glass Cylinders. W. A. Jones, Columbus, O. (U.S.A. Pat., No. **1396216**, November 8th, 1921. Filed October 18th, 1918, No. 258783).—Relates to a device for cooling cylinders contiguous to the molten glass during the drawing operation, and consists in employing for the purpose a water-cooled ring surrounding the cylinder. The ring consists of two hollow semicircular portions, 17, which are connected by means of arms, 18, with a tube, 15, pivoted on a top stone, 10, water being circulated through pipes, 19, the tube, 15, the arms and the ring section. With this construction, the two ring-sections, 17, can be swung out of the drawing-opening to allow the insertion of the bait, to permit a cover to be placed in the opening, or to enable the cylinder to be burnt-off from the metal.

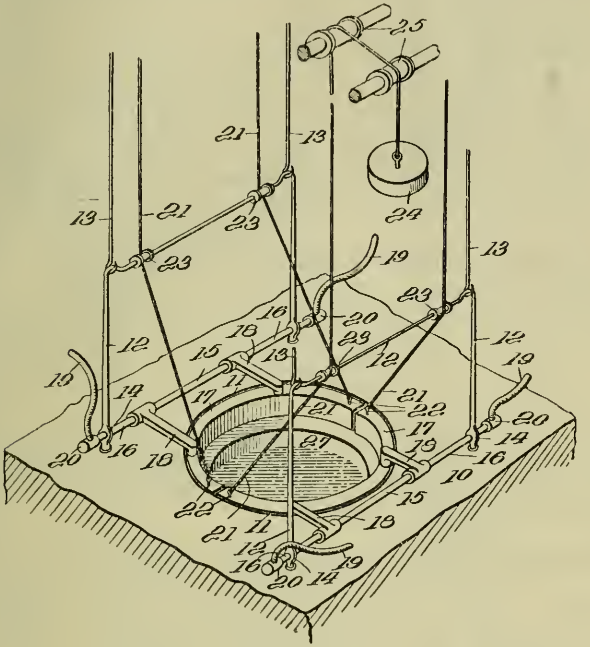

Fig. 45.

G. D.

78. Drawing Sheet Glass. R. E. Ewing, Toledo, O. (U.S.A. Pat., No. **1399547**, December 6th, 1921. Filed August 1st, 1919, No. 314626).—The invention relates to the process of sheet-drawing in which the sheet is drawn vertically upwards and is then turned over a bending-roller into the horizontal position. According to the invention, the bending-roller is internally heated so that its temperature approximates to that of the glass sheet with which it is in contact. It is stated that by this means marring of the sheet by the bending-roller is avoided and the original fine polish is preserved.

G. D.

79. Drawing Glass Cylinders. H. K. Hitchcock, Pittsburgh, Pa., assignor to the Pittsburgh Plate Glass Co. (U.S.A. Pat., No. **1398019**, November 22nd, 1921. Filed December 28th, 1918, No. 268715).—A cold bait, for drawing glass cylinders without the usual cap or neck, comprises a lower annular member, 3, having a ledge, 9, for supporting a flange on the cylinder as shown, a second member, 4, movable up and down with respect to the member 3 and adapted to engage the flange of glass when it is lowered, and means by which the second member is lowered automatically when the bait is dipped into the metal and raised off the flange when the bait is lifted. G. D.

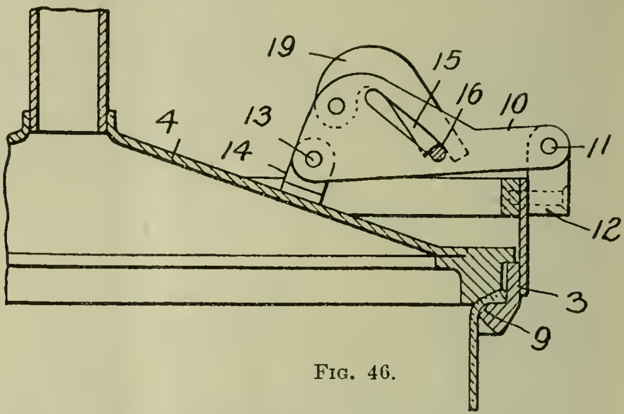

FIG. 46.

80. Drawing Sheet Glass. T. S. OWENS, Toledo, O. (U.S.A. Pat., No. **1386724**, August 9th, 1921. Filed January 14th, 1919, No. 271082). — An apparatus for drawing glass sheets, shown in side elevation in Fig. 47, consists of two pairs of endless sprocket chains, 7, supported opposite one another over the metal, 2, the chains of each pair being joined by cross-bars, 8. The bars, 8, on each pair of chains are so arranged that they make contact with those on the other and thus grip and draw the sheet, 1. The pressure between the bars weakens the sheet so that it can be broken into sections by the pressure of a roller, 9. G. D.

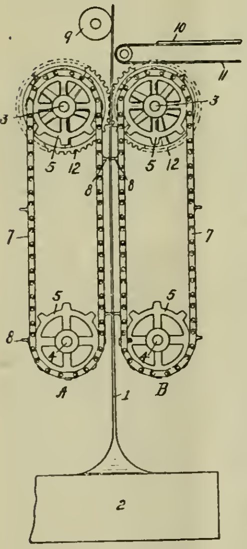

FIG. 47.

81. Drawing Sheet Glass. C. A. RHONEMUS, Charleston, W. Va., Assignor to THE LIBBEY-OWENS SHEET GLASS CO. (U.S.A. Pat., No. **1391406**, September 20th, 1921. Filed December 30th, 1919, No. 348319).—A machine for drawing sheet glass according to the Colburn process, such as that illustrated in U.S.A. Patent No. 1248809, has water-coolers, *E*, placed adjacent to the two sides of the sheet, *D*, a roof tile, *G*, placed above the flue, *H*, and the end of the tank, and a plate, *I*, of graphite or other suitable material extending from the wall, *C*, of the tank to the edge of the tile, *G*. The plate, *I*, allows the heat of the gases under the tile, *G*, and also the heat of a burner, *J*, to be transmitted to the surface glass in the tank, but prevents direct contact between the hot gases and the cooler, *E*. It has been found that without the plate, *I*, the hot gases deposit in the cooler a coating which reduces its efficiency.

G. D.

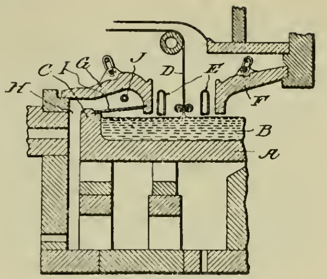

FIG. 48.

82. Drawing Sheet Glass. C. A. RHONEMUS, Charleston, W. Va., Assignor to THE LIBBEY-OWENS SHEET GLASS CO., Toledo, O. (U.S.A. Pat., No. **1391405**, September 20th, 1921. Filed April 19th, 1919, No. 291214).—The invention relates to the process of drawing glass in flat sheets and consists of means for preventing the "stringing" or narrowing of the sheet as the draw proceeds. The metal, 4, from which the sheet is drawn is contained

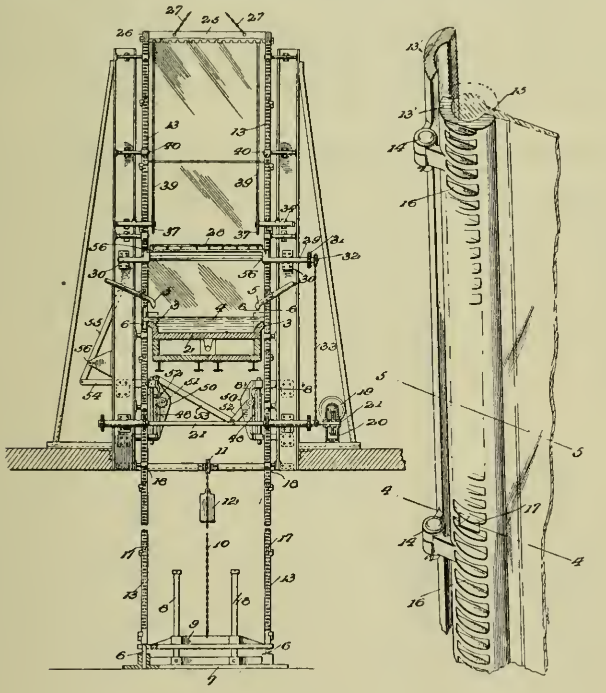

FIG. 49.

in a pot, 2, and on each side of which overflow lips, 3, are provided at points slightly below the level of the surface of the metal in the pot. Small lateral streams of metal flow outwardly over these lips and are received by vertically-moving tubes or channels, 13. The tubes are split longitudinally into two sections, and the sections are hinged along the outer edges, the inner edges being slightly separated so as to leave a slot, 15. The tubes are formed with rack teeth 16, so that they can be moved upwards by pinions driven by a motor. The metal flowing over the lips, 3, runs through the slots, 15, into the tubes and thus forms an anchor which maintains the sheet of uniform width as it is drawn.

In order to facilitate the breaking up of the sheet, it is scored transversely by blades, 28, rotated about shafts, 29, and longitudinally along lines, 39, by wheels, 37. The sheet is broken up along the scored lines and the smaller sheets are transferred to the lehrs.

Another U.S.A. Patent * relates to an improvement on the above invention and consists in replacing the tubes, 13, by a series of tubular or cup-shaped members and in providing means for placing these members end to end. In the form of apparatus described, the short tubular members are secured to endless bands travelling alongside and parallel with the edges of the sheet. Air is exhausted from each section as it passes the overflow lip of the pot in order to draw the metal into the tube. G. D.

83. Drawing Sheet Glass. E. Rowart, Auvelais, Belgium (Brit. Pat., No. **167347**, May 31st, 1920).—Relates to apparatus for drawing sheets of glass arranged to maintain the glass up to the point of draw at uniform temperature. The glass is drawn from the narrow trough-shaped upper part, 16, of a funnel, the lower part, 14, of which is formed with a downwardly enlarged channel, 17. The funnel is supported in the bottom of a chamber, 5, which is inserted in the upper part of the tank, 1. When drawing is taking place, the lower part of the funnel is immersed in the molten metal, 2, to such

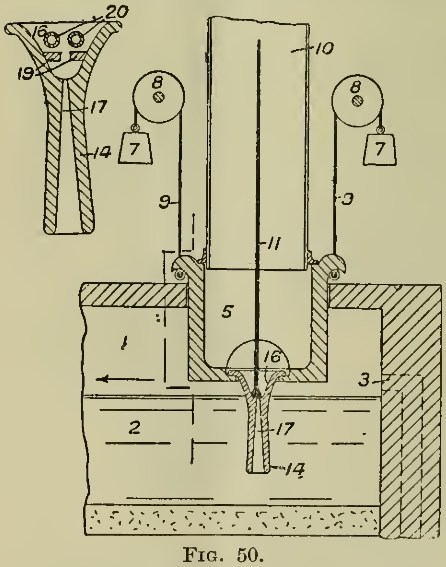

Fig. 50.

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* By R. F. Callard and C. A. Rhonemus, Charleston, West Virginia, Assignors to the Libbey-Owens Sheet Glass Co., No. **1393081**, October 11th, 1921. Filed May 21st, 1919, No. 298666.

an extent that a meniscus forms in the part, 16. Hot gases from conduits, 3, circulate round the upper part of the funnel and under the chamber, 5. The chamber, 5, or part of it, is mounted so that it can be raised to lift the funnel clear of the glass to allow the glass to melt out. In the arrangement shown, the chamber is supported by counterweights, 7, on cords, 9, passing over pulleys, 8. The construction of the funnel is shown in detail in Fig. 50. Cooling-pipes, 20, are arranged near the drawing point and shields, 19, are disposed under the pipes to prevent the glass from being cooled. The drawn sheet, 11, passes up through a tunnel, 10, as usual. H. G. C.

84. Simultaneous Drawing of Two Sheets of Glass. J. P. Crowley, Toledo, O., Assignor to the Libbey-Owens Sheet Glass Co. (U.S.A. Pat., No. **1394283**, October 18th, 1921. Filed June 4th, 1920, No. 386440).—Relates to the process of drawing sheet glass in which the sheet is drawn vertically and then passes over a bending-roller, *G*, and proceeds in a horizontal direction. The invention consists in drawing two sheets together so that they make contact with one another when passing over the roller, *G*, and are sufficiently cooled not to adhere. The upper sheet, having been in contact with glass only, will be of high quality, whilst the lower sheet, although it may be somewhat marred by contact with the roller, *G*, and the drawing-table, is still of saleable quality.

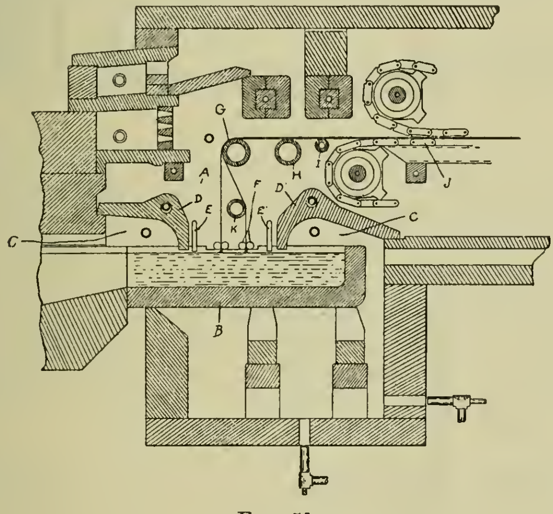


Fig. 51.

G. D.

85. Improvements in the Libbey-Owens Sheet Glass Process. M. J. Owens, Toledo, O., Assignor to the Libbey-Owens Sheet Glass Co. (U.S.A. Pat., No. **1397326**, November 15th, 1921. Filed June 27th, 1917, No. 177181).—Contact with the bending-roller in the Libbey-Owens process has a more or less injurious effect on the surface of the glass, and the invention consists in replacing the bending roller by a device having a sliding-contact with the glass in order to avoid the marring effect.

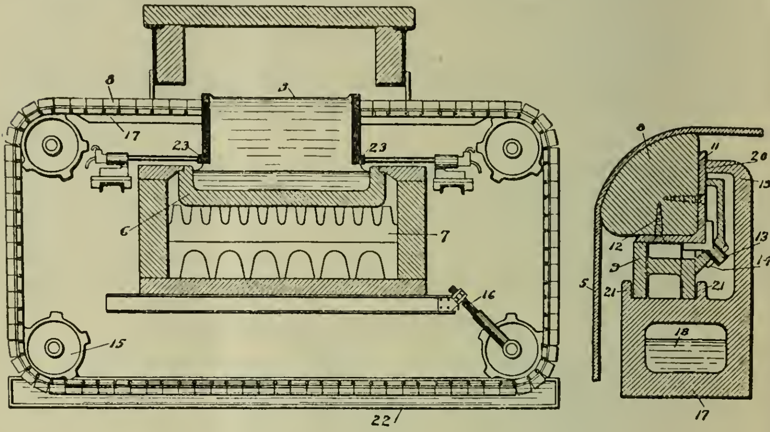


Fig. 52.

The bending-device, according to this invention, consists of a series of quadrant-shaped wooden blocks, 8, shown in side elevation in Fig. 52, over which the sheet, 5, passes. In order to secure sliding contact between the blocks and the sheet, the blocks are flexibly connected in the form of an endless chain, which is driven continuously so that the blocks slide along the under surface of the sheet, 5. The lower run of the chain passes through a water trough, 22, so that the blocks are kept cool and wet. Metal blocks, surfaced with a paste such as is usually used for pasting moulds, may be used instead of wooden blocks. G. D.

86. Casting Plate Glass. J. W. Kunzler, Pittsburgh, Pa. (U.S.A. Pat., No. **1396330**, November 8th, 1921. Filed April 19th, 1917, No. 163134).—The invention consists of a device for receiving metal from a tank furnace and spreading it out on the casting table. As shown in sectional elevation in Fig. 53, the device consists of an horizontal cylinder, 6, of metal lined with fireclay, which at one end is fitted with a flue, 22, and at the other end fits around a discharging nozzle, 3, formed in the side of the tank, 2. The cylinder is rotatably supported on rollers, 16, and has a longitudinal opening, 8. The casting table, 9, runs on rails close below the cylinder, its direction of motion being at right angles to the cylinder. The roller, 11, is mounted on fixed standards, 14,

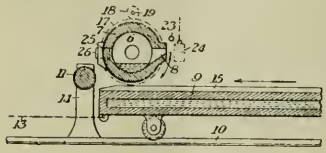


Fig. 53.

alongside and parallel with the cylinder, its bearings being arranged to allow it to rise and fall freely.

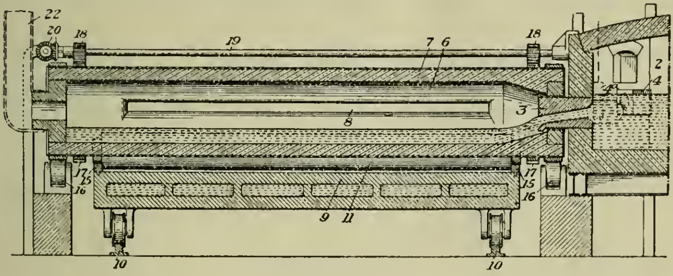


Fig. 54.

In use, metal runs from the tank into the cylinder, and when the proper quantity has entered, the table is started and the cylinder is turned on its axis, so that the metal runs out of the opening, 8, and is thus spread out in front of the roller. A block, 24, closes the opening, 8, while the cylinder is charging, and gas jets inside the cylinder enable the temperature of the metal to be regulated.
G. D.

87. Water Jackets for Preserving Straightness in Drawn Sheet Glass. O. P. Marconet and W. O. Carter, Clarksburg, W. Va. (U.S.A. Pat., No. **1398109**, November 22nd, 1921. Filed March 19th, 1920. No. 367200).—Relates to the process of drawing glass in flat sheets and consists of means for preserving straightness and uniformity in width of the sheet as it is drawn. For this purpose, the invention consists of the use of water-jackets, *C*, surrounding the edges of the sheet and situated close to the metal from which the sheet is drawn. The edges are thus chilled and hardened before the body of the sheets and preserve the width and straightness of the sheet. The water-jackets, as shown in plan in Fig. 56, are preferably of cylindrical form and provided with a longitudinal slot extending the entire length of the jacket. The

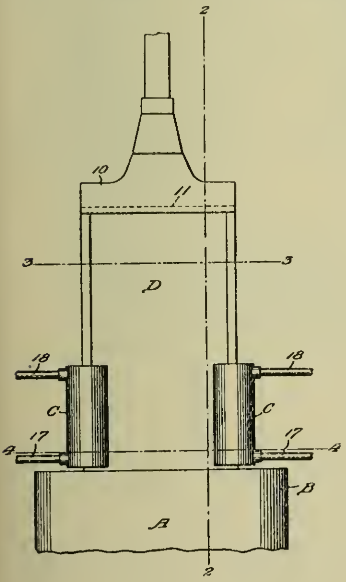


Fig. 55.

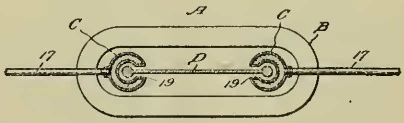


Fig. 56.

bait, 10, may consist of a single element having a cylindrical groove along its lower edge, or it may consist of two sections hinged together along the top edge so that they can be separated to release the sheet. G. D.

88. Making Corrugated Wire Glass. A. Shuman, Philadelphia, Pa., Assignor to the Pennsylvania Wire Glass Co. (U.S.A. Pat., No. **1397149**, November 15th, 1921. Filed February 3rd, 1920, No. 356015).—The invention consists in making a corrugated sheet of wire glass by rolling the metal on a corrugated table, on which the wire mesh has been arranged, by a corrugated roller, and then subjecting the sheet, while still hot, to a pressing-operation with a corrugated press in order to free the surface of the glass from gashes and marks which may have been made upon it. An apparatus for carrying out the process is described and claimed in the specification. G. D.

89. Cooling Glass-rolling Machinery. A. Shuman, Philadelphia, Pa., Assignor to The Pennsylvania Wire Glass Co. (U.S.A. Pat., No. **1382608**, June 21st, 1921. Filed February 18th, 1920, No. 359721).—Relates to rolling tables, and rollers which are cooled by circulating water through channels of circular cross-section, and consists in inserting in each channel, 3, a rod, 5. A crescent-shaped space, 6, is left in each channel, thus applying the water in thin streams of large area and minimising the quantity of water required. G. D.

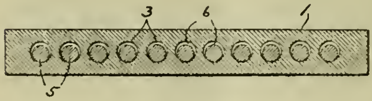


Fig. 57.

90. A Water-cooled Glass Roller. W. Cox, Philadelphia, Pa., (U.S.A. Pat., No. **1392626**, October 4th, 1921. Filed January 19th, 1920. Serial No. 352580).—A roller used for rolling glass has a circular row of water channels, 2, arranged parallel with the axis and near the surface of the roller, thus providing between and around them a metal core and solid metal supports. The purpose of the invention is to prevent warping of the roller due to uneven heating when the metal is poured on the table. G. D.

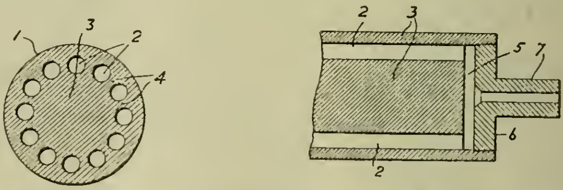


Fig. 58.

91. Glass-cooling Mechanism. J. Sonderberg, Pittsburgh, Pa., Assignor to the Pittsburgh Plate Glass Co. (U.S.A. Pat., No. **1398046**, November 22nd, 1921. Filed July 21st, 1919, No. 312131).—In order to prevent distortion of the roller, it is kept in rotation during successive rolling operations and is thus prevented from becoming unequally heated. Air jets or gas jets are directed on to the surface of the roller while it is in rotation in order to maintain its temperature at any desired point. Endless chains passing over driving sprockets and sprockets on the shaft of the roller are used for traversing it along the table. The construction of the mechanism is described and illustrated in the specification. G. D.

92. Tumbler-grinding Machine. A. B. KNIGHT, Fairmont, W. Va., U.S.A. (Brit. Pat., No. **165668**, July 6th, 1920).—A

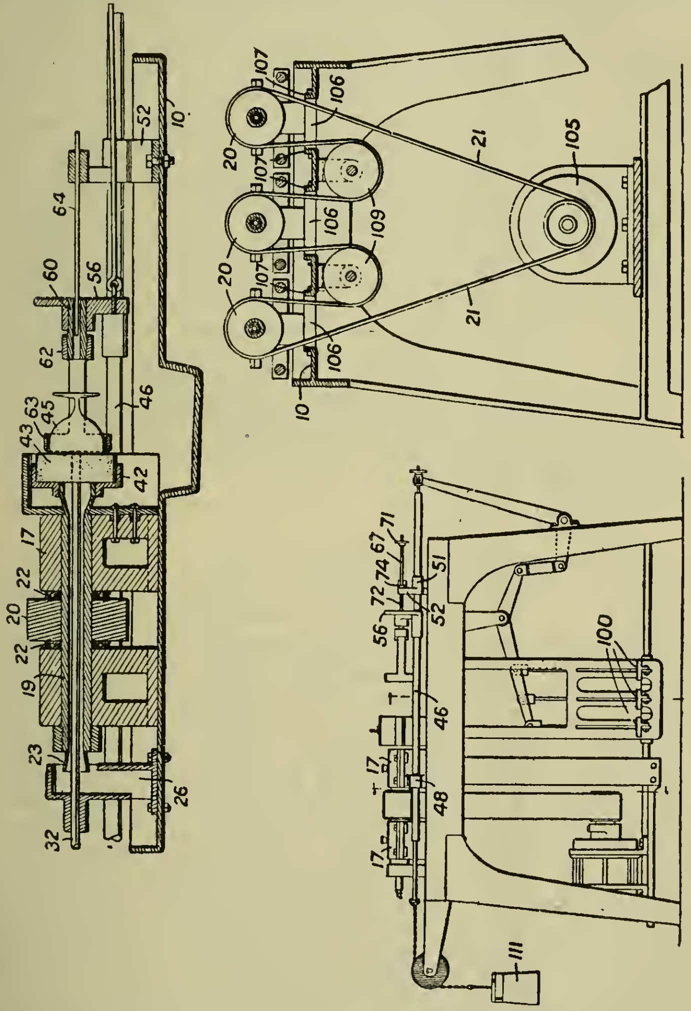


FIG. 59.

machine for grinding glassware, especially the cracked-off ends of tumblers, etc., comprises a number of similar units, all the grinders being driven by a single belt. The machine shown has three units, each of which comprises a grinding-wheel, 43, Fig. 59, and a holder, 63, for the drinking-glass, 45, being ground. Each grinder, 43, is carried by a chuck, 42, on the end of a tubular spindle, 19, which is supported in bearings, 17, and is rotated by a pulley, 20, between ball bearings, 22. Water is supplied through a pipe, 32, concentric with the spindle, 19, and the waste returns through the spindle, the coned end, 23, of it throwing the waste away from the bearings, 17, into a housing, 26. The ring, 63, is lined with leather or other fibrous material, and forms part of a clutch, 62, on a carriage, 56, which is carried by a pair of rods, 46. These rods are slidable in sleeves, 48, carried by one of the bearings, 17, and in sleeves, 51, on a bracket, 52. The carriage, 56, is moved towards the grinder by weights, 111, and away therefrom by a treadle, 100. The levers connecting each treadle to its corresponding carriage are so proportioned that equal depressions of the treadles produce equal movements of the carriages. The forward movement of the carriage, 56, is limited by an adjustable nut, 71, on a rod, 67, sliding through an aperture in the bracket, 52, and attached to the carriage, 56. A latch, 74, on the bracket, 52, can be turned to engage a flattened portion, 72, of the rod, 67, and hold the carriage, 56, in its inoperative position. The bracket, 52, carries an adjustable rod, 64, which passes through the carriage, 56, and contacts with the rear of the work as the carriage is withdrawn, thereby ejecting the work. The several units are driven from a motor, 105, by a belt, 21, passing over the pulleys, 20, and under idler pulleys, 109. Openings, 106, in the support, 10, allow the belt to pass therethrough, and are provided with upstanding edges, 107, to prevent overflow of water. H. G. C.

93. Machine for Bevelling Lenses. W. J. Druiff, London (Brit. Pat., No. **163950**, September 8th, 1920).—A spectacle or other lens is rotatably carried by a pivoted frame, which is swung automatically at intervals to present opposite sides of the lens to an axially reciprocating grinding-wheel, and is moved under the control of a templet to secure the desired shape of lens. On a table, 1, is mounted in bearings, 2, 3, a belt-driven shaft, 4, carrying a grinding-wheel, 6, moved axially by a cam, 20, which is rotated through toothed gearing, 13, 13*a*, 15*a*, and worm gearing, 7, 9, by the shaft, 4, and engages rollers, 19, carried by a fork, 17, rotatably mounted on the shaft. The lens, *x*, is mounted on a carriage having a plate, 32*a*, pivoted, at 32, to the table and adapted to be swung, to present opposite edges of the lens alternately to the grinding-wheel, by a rod, 29, mounted beneath the table and slotted to engage a pin, 31, carried by the plate. The rod is pivoted to a link, 28, which is pivoted to the table and to a longitudinally slidable rod, 26, carrying rollers, 25, engaged by a cam, 24, carried by a shaft, 22, and rotated, through bevel-gearing, 21, 21*a*, by the shaft, 10, of the worm-wheel, 9. On the plate 32*a* is mounted a slide, 33, provided at its ends with lugs, *c*, *d*, forming bearings for a spindle, *a*, on which is pivotally mounted a frame, 38′. This frame carries, in bearings, 38*a*, 38*b*, thereon, two spindles, 40, 41, each carrying a head whereby the lens, *x*, is clamped between the spindle. The spindles are rotated in the same direction and at the same speed, through gearing 62, 63, 64, 62*a*, 63*a*, and the spindle, *a*, by a shaft, 45, having therein universal joints and driven, through bevel and chain gearing, by the shaft, 10. The slide, 33, is movable on the plate, 32*a*, by a screw, 34, having a milled head, 34*a*, automatic operation of the slide is brought about by means of a ratchet-wheel, 36*a*, on the screw operated by a pawl, 38, carried by a spring-pressed arm, 37, which is struck at each angular movement of the carriage to the left, Fig. 61, by an adjustable stop, 39, carried by a bracket, 40*x*. The feed is stopped by an adjustable shroud for the teeth of the ratchet-wheel or by constructing the wheel so that some of the teeth are missing. The spindle, 40, may be moved to accommodate lenses of different thicknesses by a micrometer screw, 42, and the spingle, 41, may be moved by a nut, 41*c*, mounted in ball bearings, 41*d*, and engaging a screw-thread, 41*b*, on the spindle. On the outer end of the spindle, 41, is mounted a templet, 54*a*, having an outline corresponding with the finished shape of the lens and engaging a plate, 55, carried by a projection, 56, on the slide, 33. The plate may be adjustable towards and from the templet to allow of variation of the size of the lens or to compensate for wear; for this purpose, the plate is mounted on an arm, 55*a*, Fig. 61, pivoted to the slide and pressed by a spring towards a vertical member, 57, forming a backing for the arm and carrying a screw, 58, for adjusting the

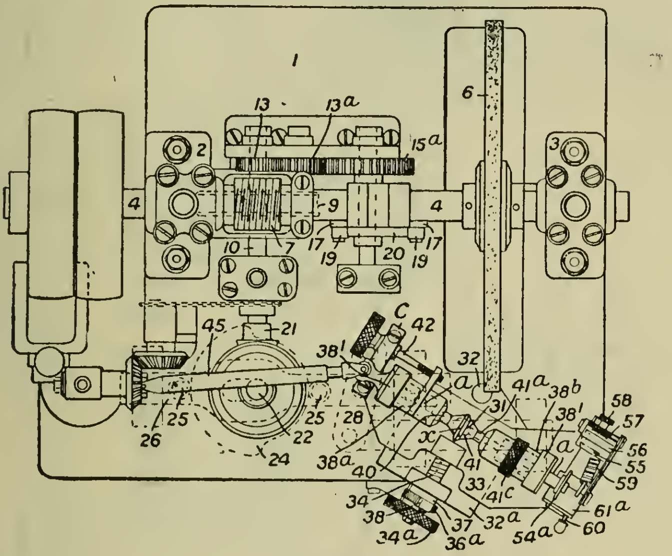


FIG. 60.

arm. The templet is pressed against the plate, 55, by a spring, 59, connected at one end to the member, 57, and at the other end to a rod, 60, which is slotted to engage the edge of a hole in a plate, 61*a*, pivoted on the spindle, *a*, whereby the plate presses against the templet. In order that the lens may be withdrawn from the grinding-wheel when being swung over to operate on the opposite side, the spindle, *a*, drives, through chain gearing, a cam, 69, carried by a spindle, 68, mounted in the member, 57, and having a projection, 70, contacting with the back of the plate, 55, or its support and adapted to press back the lens carriage at the required moment.

H. G. C.

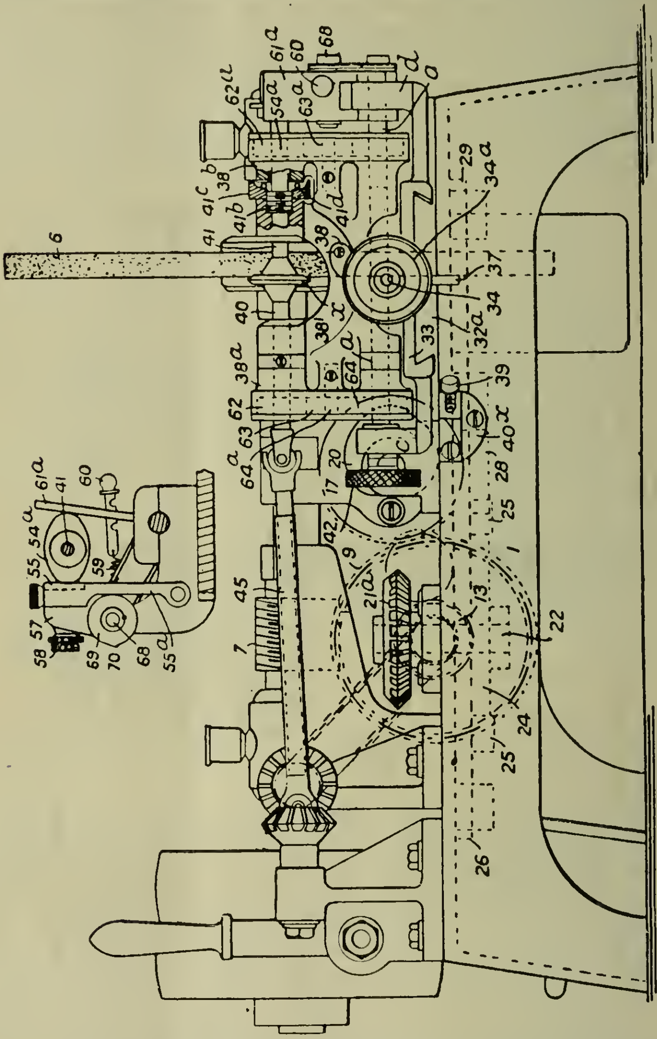


Fig. 61.

94. Cutting Glass Tubing, etc., into Lengths. BRITISH THOMSON-HOUSTON CO., LTD., London, and the GENERAL ELECTRIC CO., New York, U.S.A. (Brit. Pat., No. **162037**, January 13th, 1920).—The apparatus is described in connection with glass-drawing apparatus of the kind described in Specifications 17602/13 and 109843. The rod, etc., 6, is drawn upwards at a uniform speed. An electromotor, 20, having a corundum wheel, 18, on its spindle, is rotated about a shaft, 19, by gear engaging a wheel, 17. The edge of the corundum wheel, 18, touches the rod, etc., 6, each revolution of the wheel, 17, and scores the rod as it moves upwards at the same speed as the rod. A cam-operated arm presses the rod, 6, into contact with the wheel, 18, and another arm strikes it to break off the length, which is then delivered by an automatic device. H. G. C.

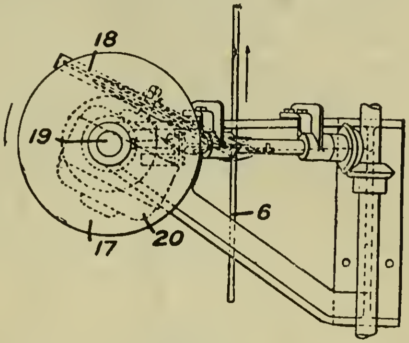


FIG. 62.

95. Lens Bevelling Machine. S. RICHARDSON, London (Brit. Pat., No. **166330**, April 9th, 1920).—A machine for bevelling the edges of lenses comprises a bevel-edged grinding-disk, 1, on a shaft, 7, and a swivel head, 21, pulled towards the disk by a spring, 25. The head, 21, is mounted between collars on a spindle, 17,

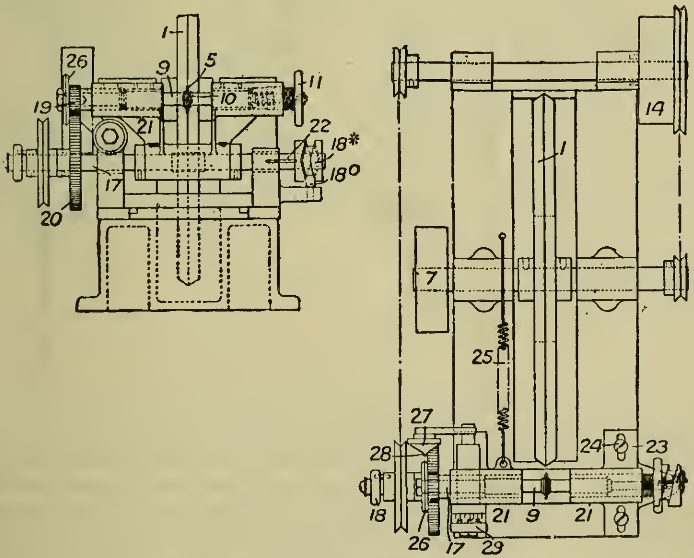


FIG. 63.

which is reciprocated by means of a cam, 18*, engaging a stationary pin, 18°. An indicator, 22, is provided so that the cam can be brought to the correct position when centring a lens. A lens, 5, carried by a spindle, 9, is held between pads, 10; a screw, 11, with spring adjustment, clamps the lens. The spindle, 9, which is rotatably mounted in the head, 21, and carries a templet, 26, is driven from the spindle, 17, by gears, 19, 20. The spindle, 17, is driven from the shaft, 7, by means of belts, an epicyclic reduction gear, 14, and a clutch, 18. The spindle, 9, 17, can be adjusted towards or from the disk by means of a plate, 23, and screws, 24. A guide plate, 27, contacting with the templet, 26, and adjusted by a micrometer screw, 29, may have a protuberance, 28, so as to prevent the lens from grinding on the line of junction of the bevel-edges of the disk. A number of disks may be mounted on the same shaft so as to operate simultaneously on a number of lenses. In a modification, the disk has an axial reciprocation instead of the lens-carrying spindle. H. G. C.

96. Machine for Ornamenting Glass-ware by Cutting. S. E. Page, London, and J. B. Greer, Pittsburgh, Pa., U.S.A. (Brit. Pat., No. **166819**, July 17th, 1920).—A machine for ornamenting glassware by grinding has a series of mechanisms which give an intermittent step-by-step rotation to a tumbler, etc., whilst grinding-wheels are automatically moved towards and cut the glass when it is held at rest. Fig. 64 (left) is a rear view of the machine, Fig. 64 (right) is a side elevation with one of the sides removed, and Fig. 65 show details of the feeler and slide mechanism. The chuck, which comprises two sets of spring-adjusted radial fingers, 47, 48, each surrounded by rubber bands, is mounted to rotate on an inclined hollow shaft, 18. For placing a tumbler in position on the chuck, the fingers are first retracted by pressure on a knob, 44, of a slidable bar, 41, within the shaft, 18, this bar carrying conical members, 52, 54, normally holding the radial

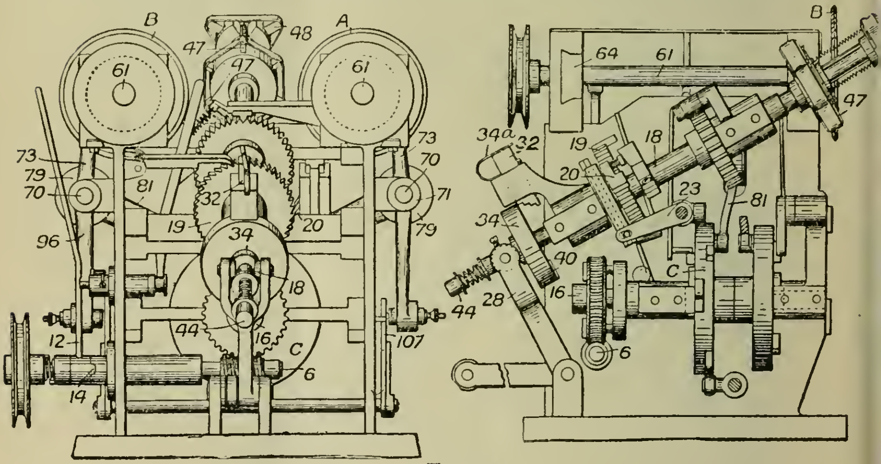


Fig. 64.

fingers extended by the action of springs, 43, 57. The shaft, 18, is given a step-by-step motion from a cam, *C*, through a rocking-shaft lever, 23, a slide and pawl, 20, and a ratchet-wheel, 19, the cam-shaft, 16, being driven through worm-gearing by the main belt-driven shaft, 6. The grinding-wheels, *A*, *B*, on belt-driven shafts, 61, mounted in sliding blocks, 63, 64, are moved towards and away from the glass by a cam-groove in the cam-wheel, *C*, which, through links, 81, and friction devices, 79, imparts a rocking motion to side shafts, 70. This motion is transmitted to slide the grinding-wheel shafts towards the glass by links, 72, 73, and auxiliary shafts, 75, slidably mounted in sliding blocks, 63, 64. Sliding blocks, 83, are mounted in adjacent slides and are provided with a feeler, 84, to limit the advance of the grinding-wheels, the feelers being moved by rocking the shafts, 75, far enough to allow them to touch the glass. A restraining-screw, 88, on each block, 63, 64, is then set to engage a projection, 86, on the feeler slide, 83, to prevent the grinding-wheel from cutting the glass too deeply. The feeler slide, 83, is temporarily locked, when the chuck is at rest by a cam-operated locking device. To limit the amount of withdrawal of each grinding-wheel, a stop-wedgepiece, 107, is

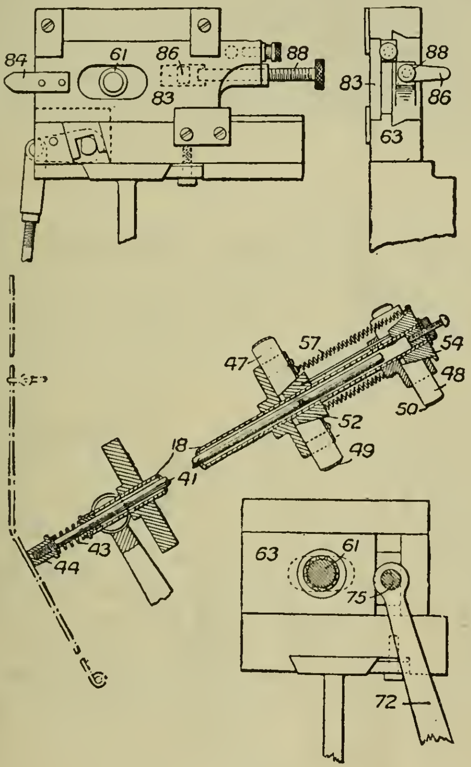


FIG. 65.

applied to an extension, 96, of the arm, 73, but the cam movement is able to continue on account of the friction drive. To cut a number of ornamental circular bands on the glass, the chuck shaft is automatically slid axially by a spring-pressed bell-crank lever, 28. A step-ended bar, shown in Fig. 64, holds the chuck shaft in position against the spring-pressed lever, 28, by bearing against a flanged wheel, 34, fixed on the shaft. After each revolution, the cam, 40, on the wheel, 34, presses the stepped bar upwards against a spring, 34*a*, and allows the spring-pressed lever, 28, to move the whole chuck shaft axially a distance of one step until the wheel, 28, engages the next step of the bar. On completion of the last cut, a trip-finger on the chuck shaft operates a lever, which moves the starting-lever, 12, to disengage the clutch, 14, on the main shaft, 6. H. G. C.

X.—Glassware Accessories.

97. Bottle-washing Machine. E. Zangerlu, Charenton, Seine, France (Brit. Pat., No. **161518**, April 2nd, 1921. Convention date, April 9th, 1920. Not yet accepted).—A rotary drum, 1, is provided with rows of pivotally mounted perforated cells, 3, into which bottles are fed at the right-hand side of the machine and are carried through a vat, 2, containing a cleansing liquid such as potash solution, the bottle being discharged on to a tray, 21, after being first rinsed by clean water jets supplied from a pipe, 14. Each row of bottle-containing cells is mounted on a shaft, 9, provided with a lever, 8, having a roller, 10, for engaging a cam surface, 11. Springs, 12, maintain the bottom edge of the cells in engagement with stops, 13, on the drum as the bottles pass through the vat solution, the bottle necks engaging between slots, 7, in oppositely-placed curved stop members, 6, on the drum

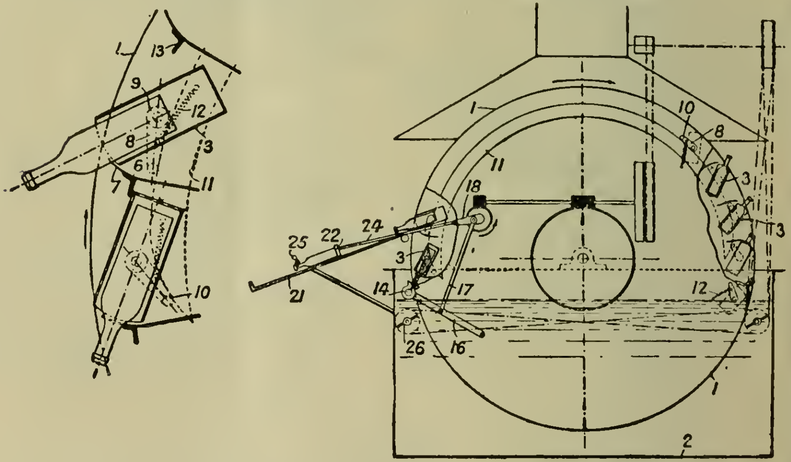


Fig. 66.

until the rollers, 10, engage the cam surface, 11. The cells are then moved against the action of the springs into a position so that the bottles are discharged by gravity, the empty cells then being positioned so that fresh bottles to be cleaned may be inserted at the other side of the machine. Previous to the discharge movement, the nozzles on a rinsing pipe, 14, register with the bottles and inject clear water to rinse the inside of the bottles. This rinsing device is operated through links, 16, 17, and a crank, 18, on a shaft driven by the gearing rotating the drum, 1. A cross member, 22, on an arm, 24, connected to the crank, 18, stops the bottles as they are discharged on to the tray, and this member, 22, is then lifted into a position behind the bottles to then push them down towards a receptacle. During this movement, the bottles are rinsed from a tap, 25. Rotary agitators, 26, are provided to keep the temperature of the vat more uniform and to remove cork, etc., from the surface where the bottles leave the cleansing liquid. H. G. C.

98. **Machine for Washing Bottles.** G. C. THOMSON, Roslyn, Dunedin, New Zealand (Brit. Pat., No. **159826**, July 26th, 1920. Convention date, August 7th, 1919. Not yet accepted).—Relates to machines in which bottles are carried by a conveyer through various cleansing compartments, and consists in a tank constructed, shaped, and inclined to facilitate drainage, and the separation of solids from the cleansing solution. Labels and other rubbish collecting in the compartment, *V*, in which the bottles are sprayed, are removed by a belt, 67, with serrated rubber scrapers, 66, which carry the débris to a conveyer, 74, discharging to a tank, 80, and adhering trash being removed from the conveyer by a cylindrical rubber brush (not shown). The screened water flows to the chamber, 75, solids settling and being discharged from a pipe, 95, and liquid rising and flowing into the compartment, *U*, the floor of which is divided into two similar pumps, each with a false bottom, 99, and a connecting valve, 100. The first pump receives water from the chamber, 75, and overflows into the second pump, from which the suction for the sprayers is taken. The lower compartment of each pump can on closing the valves, 100, be cleared of heavy matter. The feed to the tank is regulated by a ball float, an overflow pipe being provided to drain off surplus water and incidentally indicating the degree of pollution of the water. The doors at each end of the tank consist of a series of hinged flaps, 127, Fig. 67, mounted on spring hinges, 128*a*, and shaped to conform to the bottle outline. H. G. C.

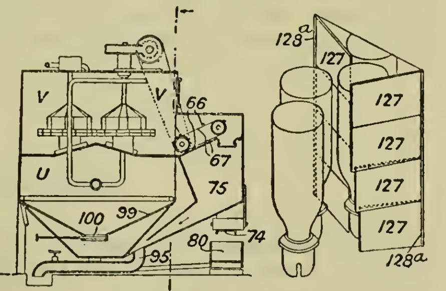


FIG. 67.

XI.—General.

99. Bottle Shapes. G. P. NELSON (*Glass Container*, 1921—2, **1**, No. 3, 12).—The shapes and sizes of bottles depended largely on their use. Lips and necks had been designed to permit the use of some particular closure; shoulders had been squared, sloped, or eliminated to give strength; bases had been widened or narrowed to furnish greater stability, or more perfect proportion. The call for constant contact of a cork and wire had been met by the round-bottomed bottle, stored on its side. Indented bottoms are essential to stability, but the " push-ups " tended to collect and hold sediment, although they might strengthen bottles used for " high-velocity " beverages. The " giraffe "-like neck found in some bottles fitted the hand perfectly. Square shoulders did not mean strength; in fact, strength increased as angles approach the straight side, or perfect curve.

A viscous liquid required a wide-mouthed, straight-sided tumbler, whilst a free-flowing liquid required a narrow-mouthed bottle. In container design, size of opening, cubic contents, and strength should all be considered in proper relation. Convenience to customers, stability, attractive and yet unique appearance should also be considered if successful sale was desired. V. D.

Reviews.

Pulverised Coal Systems in America. By L. C. HARVEY, (H.M. Stationery Office, 1922. 118 pp. Price 5s. net).—This publication consists of a special report of the Fuel Research Board. It is a timely and valuable publication on a subject of very considerable interest at the present time. The chief applications of this system of using coal in America appear to be for boilers, locomotive engines, and certain metallurgical processes. The report discusses the suitability of various types of solid fuel for conversion into the pulverised form, the cost of installation for preparing the fuel, methods of transport to the burners, types of feeders, mixers and burners, and details of the application of the system to various metallurgical processes, boilers, railway locomotives for marine propulsion and the heating of domestic and office buildings. It is stated that several installations of importance are being made on the Continent, but so far the system is only under discussion in this country. No application, even in America, appears to have been made to glass works operations. W. E. S. T.

The Physics and Chemistry of Colloids and their Bearing on Industrial Questions. (H.M. Stationery Office, 1921.

190 pp. Price 2s. 6d. net).—This publication is a report published by the Department of Scientific and Industrial Research of a general discussion held jointly by the Faraday Society and the Physical Society of London. The subject of colloidal materials and their properties is one of the fascinating subjects of modern science, and there are few branches, indeed, whether of pure or applied science, in which a study of the colloidal state is not of importance. The report in question surveys a wide field, contains a general survey of the subject from the physical and chemical point of view, and a series of papers on each of the following sections, namely, Emulsions and Emulsification; the Physical Properties of Elastic Gels; Glass and Pyrosols; Non-aqueous Colloidal Systems; Precipitation of Disperse Systems and Electric Endosmosis and Cataphoresis. The only paper of consequence in the section Glass and Pyrosols is a short contribution on the nature of glass by M. W. Travers in which there is discussed the bearing on the subject of several important recent researches such as the annealing experiments of Twyman and of Tool and Valasek; the thermal expansion determinations of Cragoe and Peters and the experiments on strain by Griffiths. W. E. S. T.

Laws and Regulations Relating to Lead Poisoning. G. STONE (London: IMPERIAL MINERAL RESOURCES BUREAU. 1922. 250 pp. Price 5s. net).—The first portion consists of an analysis of the provisions, with regard to industries using lead and lead compounds, of the laws and regulations of various countries designed for the prevention of plumbism. Part two consists of the texts of the said laws and regulations. So far as the British Empire and Europe are concerned, the collection of regulations is stated to be probably complete, except in the cases where such regulations are embodied in general factory legislation. Legislation dealing with lead poisoning as a compensatable industrial disease is also quoted. A. C.

Lead. (London, IMPERIAL MINERAL RESOURCES BUREAU. 1922. 96 pp. Price 3s. net.)—The lead-mining localities of the world were briefly surveyed and details given of the production and value of lead in the years 1913—1919. The chief producing country was the United States, which mined about a third of the total supply of lead ores, but absorbed practically the whole of this for home consumption. Other large producers were Spain, Germany, Australia, and Mexico, whilst Spain and Australia were the most important exporting countries. The following table of the red lead imports and exports of the United Kingdom was of interest :—

	IMPORTS.							EXPORTS.						
	1913	1914	1915	1916	1917	1918	1919	1913	1914	1915	1916	1917	1918	1919
Quantity (long tons).	3,050	1,981	106	630	116	—	39	28	78	94	141	75	—	6
Value (£)	63,259	42,667	2,886	29,186	5,430	—	1,670	591	1,559	2,739	6,320	3,380	—	396

A. C.

Platinum and Allied Metals. (London: Imperial Mineral Resources Bureau. 1922. 84 pp. Price 2s. net.)—An account of the occurrence, properties, and uses of the platinum group of metals (platinum, palladium, iridium, ruthenium, and osmium), with details of the production and prices over the period 1913—1919. The outstanding features in the world's placer-production during the period reviewed were the serious decline of the Russian output (157,735 crude oz. troy in 1913 to 35,000 oz. in 1920) and the increase of that of Columbia (15,000 crude oz. troy in 1913 to 35,000 oz. in 1920). The Russian decline was partly due to difficulties of labour and renewals, but also to the fact that a considerable proportion of recent years had escaped registration. Prices of platinum in London averaged 185s. per oz. in 1913, reached 770s. per oz. early in 1920, but had fallen again to 390s. per oz. at the close of 1921. A. C.

Tin. (London: Imperial Mineral Resources Bureau. 1922. 98 pp. Price 3s. net.)—A digest of the statistical and technical information relative to the production, consumption, and value of tin, particularly over the period 1913—1919, for the British Empire and foreign countries. A. C.

Gold. (London: Imperial Mineral Resources Bureau. 1922. 366 pp. Price 6s. net.)—In a detailed account of the world's sources of gold during the past few years (mainly 1913–1919) the advantageous position of the British Empire was indicated. The volume included information on the properties and the methods of mining and marketing the element. A. C.

I.—Glass-making Materials.

100. The Alsatian Potash Industry. H. VIGNERON (*J. Chem. Met. Eng.*, 1921, **24**, 655).—In the year 1904 two layers of potash salts (*sylvinite*) were discovered near Wittelsheim at depths of 1900 and 1950 feet. The deposits extended over an area of 68 sq. miles, the top stratum, 3·8 feet thick, containing 22 to 25 per cent. K_2O, the lower, 7·5 to 16 feet thick, containing from 15 to 20 per cent. K_2O. The average composition of the salts was as follows :—

	Crushed raw salts.		Refined salts.	
	Sylvinite. 14 to 16 per cent.	Rich sylvinite. 20 to 22 per cent.	KCl. 50 to 60 per cent.	KCl. 60 to 62 per cent.
K_2O	14—16	20—22	50—60	60—62
KCl	21—25	32—35	79—95	95—98
NaCl	55—67	50—55	4—5	4—0·7
$MgCl_2$	0·1—0·7	0·1—0·5	0·1—0·5	0·05—0·1
$MgSO_4$	none	none	none	none
$CaSO_4$	2—5	2—4	0·3—0·4	0·1—0·3
H_2O	0·7—1·2	0·5—1·2	0·3—1·5	0·1—0·3
Insol. clay, Fe_2O_3 ...	10—14	9—12	0·5—5	trace

The crude material was crushed and ground, then shipped as crude salts, or refined. In the refining process the material was screened, then transmitted to boiling vats. Use was made of the difference in solubility of sodium and potassium chloride in hot or cold water, and the hot solution of the mixed chlorides was separated from any insoluble matter, then allowed to crystallise, the crystallised chloride of potassium being finally dried and bagged. On the average, 3 tons of crude salts yielded 1 ton of potassium chloride, and the coal consumption was 600 lb. per ton.

V. D.

II.—Glass : Manufacture and Properties.

101. The Manufacture of Optical Glass. C. J. PEDDLE, (*Trans. Opt. Soc.*, 1921–22, **23**, 103).—A brief historical account of the production of optical glass on the large scale, a description in outline of present-day processes, and a statement of the author's results obtained by a study of the relation between chemical composition and physical properties such as density, refractive index, dispersion, devitrification, and durability.

The author pointed out that in certain glasses, particularly dense barium crown glasses, it was almost impossible to remove all the gas bubbles. Of the glass produced, at least 50 per cent. was usually rejected on examination for defects such as striæ, stones, and bad bubbles, whilst after the second examination, after moulding the pieces into slabs, the total amount of glass approved for use was only about 20 per cent. of the original.

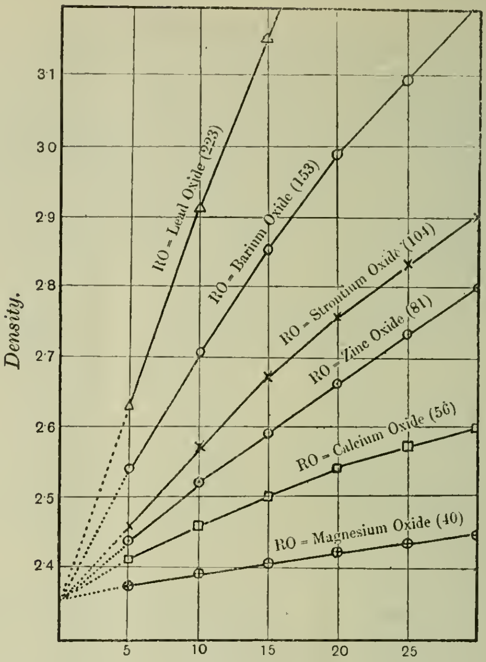


FIG. 68.

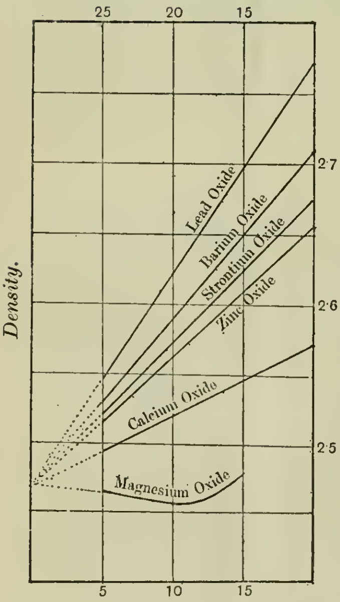


FIG. 69.

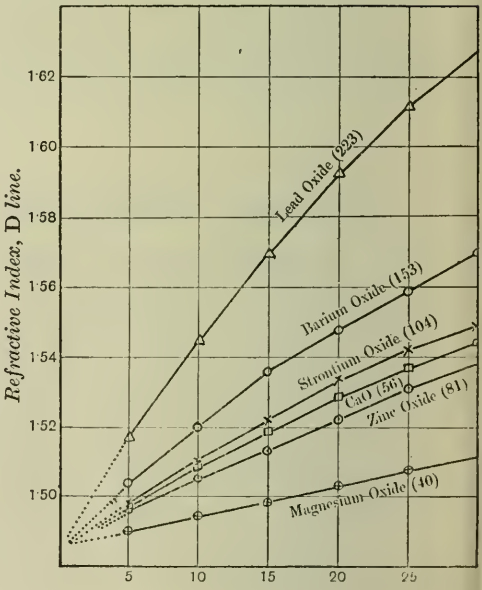


FIG. 70.

Many of the results obtained by a study of the effect of chemical composition on density, refractive index, dispersion, devitrification,

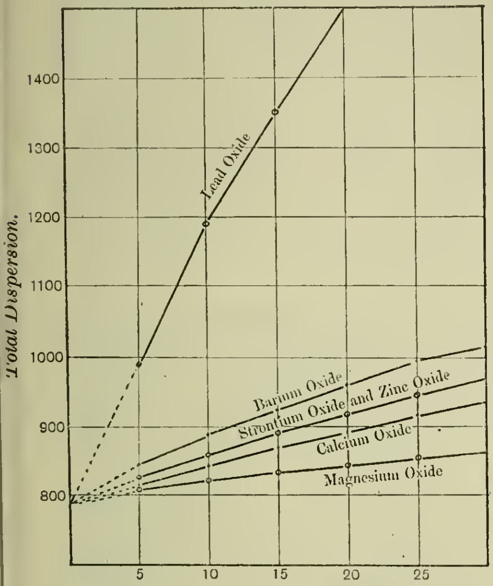


FIG. 71.

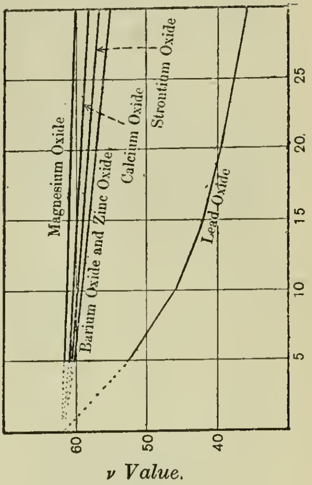
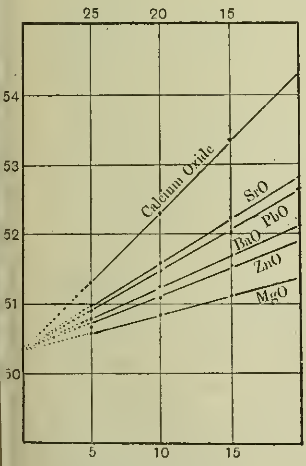
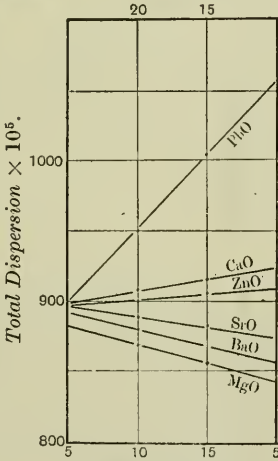


FIG. 72.



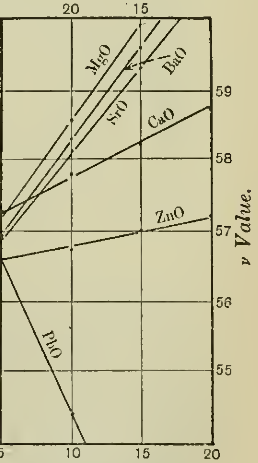
Percentage RO
(Silica 70 per cent.).

FIG. 73.



Percentage RO
(Silica 70 per cent.).

FIG. 74.



Percentage RO
(Silica 70 per cent.)

FIG. 75.

and durability have already been described by the author in the Transactions of this Journal. The results are re-stated in such a manner as to compare the effect of introducing zinc oxide and magnesium oxide into the glass with that of other oxides, namely, of lead, barium, strontium, and calcium oxides previously recorded. The following table shows that the greater the molecular weight of the oxide introduced the greater the effect on the density of the glass :

Oxide.	Molecular Weight.	Density of $100SiO_2,20Na_2O,10RO$
Lead monoxide	223	2·91
Barium oxide	153	2·71
Strontium oxide	104	2·57
Zinc oxide	81	2·52
Calcium oxide	56	2·46
Magnesium oxide	40	2·39

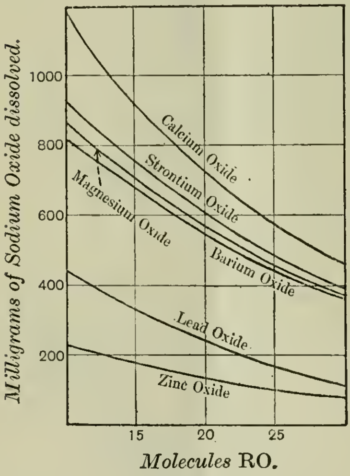


FIG. 76.

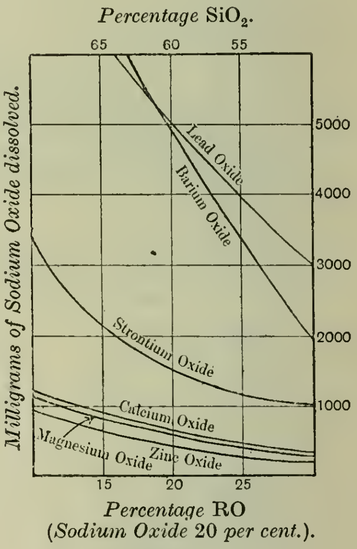


FIG. 77.

Figs. 68 and 69 set out graphically the density relationships both on the basis of percentage and molecular composition.

In glasses of the type $100SiO_2,20Na_2O,RO$ the greater the molecular weight of the RO oxide the greater the value of μ_D except in the case of zinc oxide, which has values lower than calcium oxide. It is the latter oxide, however, which is the abnormal one. Figs. 70, 71 and 72 set out the relation between molecular composition and Figs. 73, 74 and 75 the relation between percentage composition and refractive index, dispersion, and ν value. It was pointed out, that weight for weight, both calcium and strontium oxides have a greater effect on refractive index than has lead oxide. It was also noteworthy that when sodium oxide was substituted by magnesium oxide in a series in which the silica content was constant, the density fell continuously until the glass contained 10 per cent. of magnesia but the refractive index (μ_D) increased continuously.

The durability of the glasses was tested by the action of water at 80° on glass powder. It was shown that the effect of the different RO oxides on the durability was not in the order of the molecular weight. Zinc oxide was most effective in improving durability. In glasses of the SiO_2–alkali–RO type, when the total weight of alkali was less than 20 per cent. the glasses containing both alkalies in equal proportion by weight were more durable than when containing only one alkali. Figs. 75 and 76 set out the durability relationships observed.

The information given in regard to devitrification has already been recorded fully in the previous papers of the author.

W. E. S. T.

102. Method of and Apparatus for Removing Striæ from Melted Glass. S. R. Scholes, Lonaconing, Ma., L. W. Nicols, Sewickley, Pa., and W. F. Kaufman, Sewickley, Pa., all in U.S.A. (Brit. Pat., No. **171608**, November 1st, 1920, and U.S.A. Pat., No. **1370673**, March 8th, 1921). See this Journal, Abs., 1921, **5**, 110.

H. G. C.

103. Apparatus for Moulding Cup-shaped Blanks of Glass. E. A. Hailwood, Churwell near Leeds (Brit. Pat., No. **169481**, May 21st, 1920).—Relates to apparatus for moulding cup-shaped glass blanks having a shoulder, *S*. These blanks are cut at the thin part, S^1, and ground slightly to produce cylindrical glasses suitable for miners' lamps, lubricators, etc. According to the invention, molten glass is placed in a mould, *A*, having a shoulder, *S*, and a plunger, *P*, is brought down to compress the charge. Rings, R, R^1, of aluminium, etc., may be placed in the mould, *A*, so as to adhere to the glass and form the top and bottom edges. The mould, *A*, or plunger, *P*, or both, may be rotated and the plunger may have recesses, P^1, to make it grip the glass.

H. G. C.

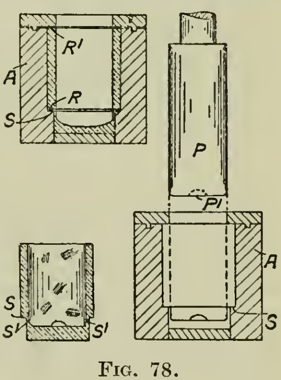


Fig. 78.

104. The Manufacture of Reflecting Telescope Discs. D. E. Sharp and W. H. Rising (*J. Ind. Eng. Chem.*, 1922, **14**, 511).—Reflecting telescope discs of 40-inch diameter and 8 inches thick were made by casting glass in a suitable mould and annealing very carefully in specially constructed furnaces. In the casting process, equipment similar to that usually used in optical glass factories was employed and the mould was made of ordinary split firebrick 9 × 4·5 × 1·25 inches, an iron casting being used as support, and to help to preserve uniformity of temperature. Talc was used to prevent adherence of the glass.

The necessary uniformity of temperature, and suitable control in cooling, during annealing, were achieved by the use of both electric and gas furnaces, the latter being found simpler in use, and more trustworthy. Special equipment was required for obtaining accurate rates of cooling, the Leeds and Northrup electrical control, and a slightly modified form of the Robertshaw gas regulator proving quite satisfactory.

The annealing was conducted on the lines of the schedule of Adams and Williamson (*J. Franklin Inst.*, 1920, **190**, 850), but a further safety margin was allowed, for instance, the 40-inch discs were maintained at their annealing temperature for fourteen instead of seven days.

Since, for reflecting discs the weathering qualities were very important, rather than optical properties, the glass was found satisfactory if made of the composition of a good crown glass. The composition of the glass actually used was as follows: SiO_2, 70·8; K_2O, 14·4; Na_2O, 5·4; CaO, 2·0; B_2O_3, 7·2; As_2O_3, 0·2 per cent.

This glass had a coefficient of linear expansion of 0·000009. The use of a glass of low expansion minimised the change in figure of a parabolic mirror on change of temperature, but, on the other hand, glasses of low expansion coefficients were more difficult to get free from bubbles. V. D.

105. Lens-forming Process. G. S. Dey, Assignor to American Optical Co., Massachusetts (U.S.A. Pat., No. **1416947**, May 23rd, 1922. Filed January 3rd, 1920, No. 349292).—The chief object of this invention was the provision of means for shaping a lens blank without causing defects on the surface, thus reducing the amount of grinding to a minimum. A suitable form, which may be of carborundum, is provided, and on this slab are cut and surfaced the curves which the final lenses are to have. Since in toric lenses it is the toric surface which is the more difficult to grind, it is preferable to cut the curves in the former corresponding to the final toric surface, so that the glass blank only touches the former on what is to be the spherical surface. Flat pieces of glass are placed on the form and by heating caused to settle down to fit the curves in the former; the curves thus formed on the upper side of the glass by the shape of the depressions in the form and the thickness of the glass itself will be approximately the desired curves. In order to mark exactly the cylinder axis of the toric surface, the axis designations are marked on the glass blank with an easily fusible enamel, and this mark is placed coincident with the axis of the form before subjecting it to the heating process. The enamel thus becomes fused to the glass and marks the axis of the toric surface until after that surface has been finished.
S. E.

106. Bifocal Lenses. H. W. Hill, Assignor to American Optical Co., Massachusetts (U.S.A. Pat., No. **1400061**, December 13th, 1921. Filed March 8th, 1920, No. 363929).—This specification refers to the manufacture of bifocal lenses of the type in which the difference in focus is secured by welding together glasses with different refractive indices. A large disc or blank has a central portion countersunk and a segment of flint glass of the same curvature, but opposite sign, is fitted into this countersink and fused in in the usual way. The large united blank is then split preferably into three portions, from each of which a bifocal lens may be made having a fairly large section for near vision without encroaching on the section used for distant vision. Before the compound blank is split into three sections, a small hole is drilled through its centre so as to break the continuity of the blank, thus rendering it possible to split the blank from the edge to the centre without breaking it from one side to the other. S. E.

107. Manufacture of Bifocal Lenses. T. B. DRESCHER, Assignor to BAUSCH & LOMB OPTICAL CO., Rochester, N.Y. (U.S.A. Pat., No. **1350441**, August 24th, 1920. Filed December 4th, 1919, No. 342334).—In making bifocal lenses means of escape for the air between the two lens surfaces must be provided. This had been done by supporting one edge of the flint glass section by a metal strip or wedge, but in practice the temperature required to cause the minor lens to fall into the countersunk portion of the major lens sometimes caused distortion of the curvature of this cavity. The difficulty is overcome by the inventor by cutting the minor lens, 3, with one or more small integral projections, 4, extending beyond the lenticular surface. Thus when the two lenses are placed together the minor lens is supported in a slightly inclined position. When heated, the small lug, 4, slowly softens and allows the minor lens to sink into its position without entrapping air and without the application of such a temperature as will cause deformation of the ground and polished depression, 2, in the major lens, 1. As the projection, 4, is relatively small and outside the lenticular portion it is entirely removed in the grinding operations necessary to finish the lens. S. E.

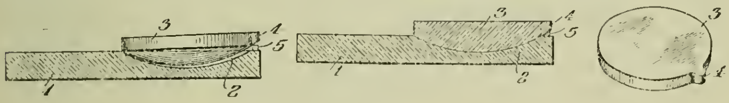


FIG. 79.

108. Preventing Condensation on Glass, etc. S. G. CONNOR and H. S. WATSON, both in London (Brit. Pat., No. **171590**, October 14th, 1920).—Condensation of water is prevented on glass by coating it with a mixture of oleic acid and alcohol or ether or chloroform in the proportion of 15 volumes of alcohol, etc., to 1 volume of oleic acid. H. G. C.

109. Making Films of Silica, Alumina, etc. M. DE ROIBOUL, Paris (Brit. Pat., No. **169136**, November 19th, 1920).—Relates to drawing films of silica, alumina, or like refractory substance having a thickness of the order of 0·001 mm. and a width of about 6 cm. Such films are stated to be strong and flexible. The apparatus employed is generally similar to that described in Specification 165052 for the drawing of filaments. Pairs of parallel wires, b^1, b^2, of iridium, etc., are passed over pulleys, c^3, and wound on a drum, n, and draw up a film, f, from a bath, a, of the molten material. The drawing may be started by a cross wire, l^1. The wires may be cut away from the film when it is subsequently unwound from the drum, or they may be severed from it as it is wound on to the drum. H. G. C.

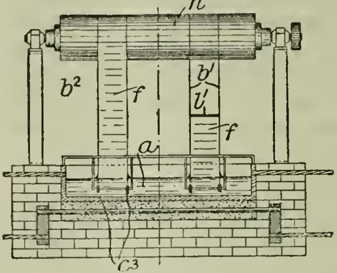


FIG. 80.

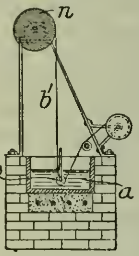


FIG. 81.

110. On Glasses Coloured by Copper. A. GRANGER (*Le Verre*, 1922, **2**, 73).—At the time of his researches on porcelain Lauth (*Génie Civil*, 1888) used a highly acid glass of the type also employed by Stas, and this glass was used at the Sèvres factory. It corresponded with the formula $3{\cdot}79\mathrm{SiO_2}\left\{\begin{array}{l}0{\cdot}54\mathrm{CaO}\\0{\cdot}23\mathrm{K_2O}\\0{\cdot}23\mathrm{Na_2O}\end{array}\right.$. Anomalies met by the author when seeking to colour this glass by the replacement of lime by copper oxide led him to study the variations in colour produced by the introduction of this colouring oxide. His attention was completely confined to commercial glasses.

For the sake of comparison the compositions of the glasses were all expressed in molecular formulæ, based on the following general form : $A\ \mathrm{SiO_2}$, $B\ \mathrm{M''O}$, $(1 - B)\ \mathrm{M'_2O}$, M″ representing a divalent metal such as calcium, lead, and more rarely zinc, barium, or magnesium. M′ represented a monovalent metal, sodium or potassium, in practice. The relation between the coefficients A, B, and (1 — B) determined the properties of the glass. The value of A lay between 2·5 and 3·5, the latter being a maximum rarely attained. B and (1 — B) lay between close limits, for a glass too rich in alkali was not sufficiently resistant to external agents, whilst a glass too rich in lime was too hard and difficult to melt. Since the blue copper colour developed best in alkaline glasses, the first glass used was represented by the formula $2{\cdot}5\mathrm{SiO_2}$, $0{\cdot}05\mathrm{CuO}$, $0{\cdot}25\mathrm{CaO}$, and $0{\cdot}7\mathrm{Na_2O}$.

The blue tint was quite distinct, and very little difference in colour was found when the $0{\cdot}7\mathrm{Na_2O}$ was replaced by $0{\cdot}7\mathrm{K_2O}$. Cooling on a cold metallic surface only caused a slight tendency to deposit copper. The blue tint was still maintained in this type of glass when the acidity was raised to $3{\cdot}5SiO_2$. The substitution of baryta, lead oxide, or zinc oxide for lime did not interfere with the development of the blue colour, but the introduction of magnesia was not so successful. In fact, with a glass containing $3SiO_2$, the blue colour developed but feebly, whilst it was found impossible to melt and fine the glass $3{\cdot}5SiO_2,0{\cdot}05CuO,0{\cdot}25MgO,0{\cdot}7Na_2O$.

Variation in the relation between the bases was studied, and it was evident that reduction of the alkali and increase of the lime created a tendency towards a green colour. The following glasses showed a distinct bluish-green tint.

$$(1)\ 2{\cdot}5SiO_2\left\{\begin{array}{l}0{\cdot}05CuO\\0{\cdot}42CaO\\0{\cdot}53Na_2O\end{array}\right. \quad (2)\ 2{\cdot}5SiO_2\left\{\begin{array}{l}0{\cdot}05CuO\\0{\cdot}45CaO\\0{\cdot}50Na_2O\end{array}\right. \quad (3)\ 2{\cdot}5SiO_2\left\{\begin{array}{l}0{\cdot}05CuO\\0{\cdot}45CaO\\0{\cdot}50K_2O\end{array}\right. .$$

Increasing the copper oxide content made the glass green, and as the acidity was low, the deposition of copper on sudden chilling was quite distinctly seen in glasses

$$2{\cdot}5SiO_2\left\{\begin{array}{l}0{\cdot}10CuO\\0{\cdot}40CaO\\0{\cdot}50Na_2O\end{array}\right. \quad \text{and} \quad 2{\cdot}6SiO_2\left\{\begin{array}{l}0{\cdot}11CuO\\0{\cdot}36CaO\\0{\cdot}53Na_2O\end{array}\right. .$$

At the same time, increasing the copper content deepened the coloration, and at a certain value it was impossible to obtain a green glass. These analogous results were to be verified on more acid glasses. Glasses containing three molecules of silica, 0·05 molecule of CuO, and increasing in lime content at the expense of the alkali, were found to show a gradual development of a green tint in place of the blue. Increasing the copper oxide content from 0·05 molecule to 0·17 molecule with a simultaneous increase in the lime content produced bluish-green glasses, but a composition of $3SiO_2\left\{\begin{array}{l}0{\cdot}10CuO\\0{\cdot}25CaO\\0{\cdot}20PbO\\0{\cdot}50K_2O\end{array}\right.$ could not be vitrified. A series of more acid glasses, containing 3·5 molecules of SiO_2, behaved in the same way. A composition of $3{\cdot}5SiO_2\left\{\begin{array}{l}0{\cdot}05CuO\\0{\cdot}70CaO\\0{\cdot}25Na_2O\end{array}\right.$ was not vitrified, and deposited copper when touched by a cold body.

Since alumina and boric oxide tended to produce green tints, the action of these two additional substances was studied. The two glasses represented by

$$3{\cdot}5SiO_2\left\{\begin{array}{l}0{\cdot}05CuO\\0{\cdot}25CaO\\0{\cdot}70Na_2O\end{array}\right. \quad \text{and} \quad 3{\cdot}5SiO_2,0{\cdot}01Al_2O_3\left\{\begin{array}{l}0{\cdot}05CuO\\0{\cdot}25CaO\\0{\cdot}70Na_2O\end{array}\right.$$

were comparable in tint; hence the action of $0{\cdot}01Al_2O_3$ was negligible.

In the glasses $\begin{array}{c}3SiO_2\\0{\cdot}5B_2O_3\end{array}\left\{\begin{array}{l}0{\cdot}05CuO\\0{\cdot}25CaO\\0{\cdot}70Na_2O\end{array}\right.$ and $\begin{array}{c}3SiO_2\\0{\cdot}5B_2O_3\end{array}\left\{\begin{array}{l}0{\cdot}10CuO\\0{\cdot}20CaO\\0{\cdot}70Na_2O\end{array}\right.$ the action of the boric oxide was very pronounced. Each of these glasses exhibited a rich peacock blue colour. Increasing the B_2O_3 content to 1 molecule at the expense of the silica produced dark glasses, appearing greenish-black by reflection.

The simultaneous addition of Al_2O_3 and B_2O_3 produced greater transparency than when the boric oxide was used alone. This was at least the case with the glasses :—

$$\begin{matrix}2{\cdot}5SiO_2\\ B_2O_3\end{matrix}\ 0{\cdot}25Al_2O_3\begin{cases}0{\cdot}15CuO\\ 0{\cdot}15CaO\\ 0{\cdot}70Na_2O\end{cases}\text{and}\ \begin{matrix}3SiO_2\\ 0{\cdot}5B_2O_3\end{matrix}\ 0{\cdot}10Al_2O_3\begin{cases}0{\cdot}05CuO\\ 0{\cdot}25CaO\\ 0{\cdot}70Na_2O\end{cases}.$$

True green colours could not be obtained from pure materials, in an ordinary glass, and it was observed that, following a formula given by Péligot, corresponding with $2{\cdot}5SiO_2\begin{cases}0{\cdot}11CuO\\ 0{\cdot}36CaO\\ 0{\cdot}53Na_2O\end{cases}$ a clear green tint was not produced. It was sufficient, however, to introduce $0{\cdot}027Fe_2O_3$ into the glass in order to make it green.

The tint of glass was intimately connected with the relation between the bases, and dependent on the alkali content. A distinct blue colour was produced with $0{\cdot}70K_2O$ or Na_2O, no matter what the acidity, and the tint became weaker when the alkali was decreased. Glasses rich in copper, of low acidity, or poor in alkali content tended to deposit copper on sudden chilling, showing that the red colour obtained from the use of copper was not merely connected with a reduction, for the composition and the cooling played an important part. V. D.

111. Colours Developed by Cobalt Oxides. H. J. WITTEREEN and E. F. FARNAN (*J. Ind. Eng. Chem.*, 1921, **13**, 1061).—The authors had collected and classified data relating to the colours which cobalt oxides exhibited either as hydrous oxides or in sintered or fused masses with metallic oxides, borates, and silicates. An extensive study was made of Rinmann's green, and in order to account for the erratic colour effects shown by the oxides alone, hydrated, or in physical or chemical combination with metallic oxides and fluxes, it was suggested that in many cases where the substances were amorphous, they were probably adsorption coagula, and, where they were crystalline, they probably were mixed crystals. This latter case was illustrated by Rinmann's green.

A certain similarity was noted between the two forms of cobalt hydroxide, and tautomeric forms of organic indicators, for example, colourless phenolphthalein, its colourless esters, and polysodium salts, and the coloured phenolphthalein esters, monosodium salt, and the insoluble silver salt.

This indicated the inadequacy of any assumptions as to ionisation and hydration as an explanation of the colour. Conclusive evidence could be expected from recent work on *X*-rays and crystal structure.

An extensive bibliography was appended. V. D.

112. Durability of Optical Glasses. (*Report of the British Scientific Instrument Research Association*, 1921).—The object of this research was to determine the possibility of, and to establish simple tests by means of which, the durability of different types and varieties of optical glass could be ascertained rapidly. Although it had been possible to produce chemical and other types of glassware stable under all conditions for which they were used, yet in the case of optical glass the problem was much more complex, certain essential optical properties sometimes entailing some sacrifice of chemical stability. The physical and chemical properties of a polished surface might differ from those of the mass of glass, and it was expected that the stability of such surfaces should differ. This was regarded as proved by the investigation.

Since the quantities involved in the measurements on stability were very minute, sensitive methods had to be devised, and it did not appear possible to decide on a simple method applicable to all types of glass.

The durability of an optical glass was regarded as its power of keeping its surface optically perfect, and free from any decomposition products, giving rise to dimming, or tarnishing, or the formation of any liquid-like, opaque, or crystalline deposits, the result of hydrolysis. Certain types of glass, such as some borosilicates, could undergo appreciable hydrolysis without apparent deleterious effects, whilst in lead glasses the slightest hydrolysis produced most marked effects. The effect was emphasised on storing these glasses after such treatment, due to the further production of opaque compounds.

The determination of the alkalinity both of a freshly fractured and of a polished surface of glass after exposure to a moist atmosphere for a definite period was made by iodoeosin solution. The effects produced by varying the conditions of weathering were also studied, as well as methods of testing with reagents such as pyrocatechin, dilute acid and alkaline solutions, and acid vapours, but on the whole iodoeosin was preferred. In order to hasten the effects of weathering, polished specimens of glass were subjected to the action of water at high temperatures for a definite time and graded according to the amount of visible corrosion which had taken place. The actual amount of hydrolysis of each glass was determined by the alkali extracted. The loss in weight was also determined. Autoclaving polished and fractured surfaces in steam was found to be of limited application, as, with short periods of heating, and low temperatures, the amount of corrosion on certain glasses rendered them unsuitable for this test. The "dimming test" (subjecting carefully cleaned polished surfaces for thirty hours at 80° to the action of air saturated with water vapour, and estimating the intensity of attack visually) was also employed.

The behaviour of moistened, finely powdered glass was investigated, and determinations made of the amount of moisture retained after drying in a vacuum, and after heating at 120°.

Estimation of Alkalinity by Iodoeosin Reaction. Iodoeosin Value. The surface of the glass was immersed for one minute in a water-saturated ethereal solution of iodoeosin. The coloured film was removed by a few c.c. of a 0·1 per cent. solution of sodium carbonate into a suitable vessel for colorimetric comparison with a standard solution of sodium iodoeosin. The results were expressed as mg. of iodoeosin absorbed per sq. dcm. of surface, and this value divided by 13·48 gave the equivalent Na_2O.

This reaction was carried out on (1) freshly fractured surfaces, (2) fractured surfaces after seven days' weathering in a moist atmosphere at 18°, and (3) surfaces fractured under the iodoeosin solution. The results in mg. per sq. dcm. were as given in Tables IA, IB, and IC.

TABLE IA.

No. and type of glass.	Iodoeosin value.		Percentage fall in alkalinity.	Classification.	Iodoeosin value. Glass fractured under soln.
	Fresh fracture.	Weathered fracture.			
1 Fluor Crown (F.C.)	0·03	0·02	33	h^1	0·03
2 Boro-silicate Crown (B.S.C.)	0·11	0·07	36	h^2	0·10
3 Boro-silicate Crown (B.S.C.)	0·08	0·03	63	h^1	0·08
4 B.S.C.	0·17	0·08	57	h^2	0·17
5 Hard Crown (H.C.)	0·16	0·07	56	h^2	0·18
6 Soft Crown (S.C.)	0·19	0·69	−263	h^5	0·33
7 Light Barium Crown (L.B.C.)	0·14	0·05	64	h^1	0·16
8 Medium Barium Crown (M.B.C.)	0·08	0·03	62	h^1	0·12
9 Dense Barium Crown (D.B.C.)	0·21	0·08	62	h^2	0·22
10 D.B.C.	0·19	0·06	58	h^2	0·21
11 D.B.C.	0·15	0·03	80	h^1	0·19
12 Telescope Flint (T.F.)	0·10	0·06	40	h^2	0·11
13 Light Barium Flint (L.B.F.)	0·10	0·03	70	h^1	0·13
14 L.B.F.	0·14	0·08	43	h^2	0·16
15 L.B.F.	0·10	0·02	80	h^1	0·11
16 Barium Flint (B.F.)	0·16	0·02	87	h^1	0·19
17 Extra Light Flint (E.L.F.)	0·12	0·08	33	h^2	0·14
18 Light Flint (L.F.)	0·08	0·04	50	h^1	0·10
19 L.F.	0·11	0·06	45	h^2	0·12
20 Dense Flint (D.F.)	0·24	0·06	75	h^2	0·20
21 D.F.	0·21	0·02	90	h^1	0·19
22 Extra Dense Flint (E.D.F.)	0·26	0·01	96	h^1	0·20

As shown by Mylius (*Zeitsch. anorg. Chem.*, 1910, **67**, 200) in the case of the heavier glasses, iodoeosin reacted with other basic components such as PbO, CaO, BaO, and MgO, as well as with the alkalies; hence these results did not strictly represent the alkali available, but they were regarded as giving a comparative measure of the chemical activity of the surfaces. For freshly fractured surfaces, the borosilicates gave lower values than either the hard crowns or soft crowns. With the lead and barium glasses the

TABLE IB.

No. and type of glass.	Iodoeosin value. Fresh fracture.	Weathered fracture.	Percentage fall in alkalinity.	Classification.
23 B.S.C.	0·12	0·08	33	h^2
24 H.C.	0·19	0·09	53	h^2
25 Z.C.	0·11	0·05	55	h^1
26 L.B.C.	0·22	0·03	86	h^1
27 M.B.C.	0·11	0·04	64	h^1
28 D.B.C.	0·24	0·09	62	h^2
29 D.B.C.	0·13	0·06	54	h^2
30 D.B.C.	0·14	0·05	56	h^1
31 L.B.F.	0·12	0·02	83	h^1
32 D.B.F.	0·18	0·02	88	h^1
33 D.B.F.	0·19	0·02	94	h^1
34 E.L.F.	0·11	0·06	45	h^2
35 L.F.	0·17	0·02	88	h^1
36 D.F.	0·19	0·06	68	h^2
37 D.F.	0·20	0·04	80	h^1
38 E.D.F.	0·20	0·02	90	h^1
38 E.D.P.	0·20	0·02	90	h^1
39 D.E.D.F. (Densest Extra Dense Flint)	0·14	0·01	93	h^1

TABLE IC.

No. and type of glass.	Iodoeosin values. Fresh fracture.	Weathered fracture.	Percentage fall in alkalinity.	Classification.	Iodoeosin value. Glass fractured under soln.
40 Fluor Crown (F.C.)	0·04	0·02	50	h^1	0·04
41 Borosilicate Crown (B.S.C.)	0·17	0·08	53	h^2	0·17
42 Silicate Crown (S.C.)	0·28	0·20	28	h^3	0·34
43 Ordinary Silicate Crown (O.S.C.)	0·20	0·30	−50	h^4	0·23
44 Soft Silicate Crown (S.S.C.)	0·41	0·58	−41	h^5	0·48
45 Light Barium Flint (L.B.F.)	0·15	0·05	66	h^1	0·16
46 Light Flint (L.F.)	0·14	0·07	50	h^2	0·16
47 Heavy Flint (H.F.)	0·23	0·02	91	h^1	0·19

results varied considerably, the iodoeosin value of fresh fractures generally increasing as the basicity increased.

All glasses except three showed a diminution in iodoeosin value after weathering, as compared with freshly fractured surface; hence weathering had rendered the surfaces less susceptible to attack. The diminution was most marked for lead and barium glasses, and increased as the PbO or BaO content increased. Weathering increased the alkalinity of the soft silicate crowns, which were regarded as disintegrating easily and having a tendency to dimming.

The difference in the results obtained by fracture under iodoeosin solution and fractured in air, were regarded as agreeing with weathering effects, except in the case of heavy flints, and soft crown glasses.

Investigation of Polished Surfaces.

Experience had shown that a polished surface was more resistant than a fractured surface, hence investigations were made on surfaces ground, polished, and cleaned under identical conditions.

TABLE IIA.

Results in mg. per sq. d.m.

No. and type of glass.	Iodoeosin values. Fresh polished.	Polished. Weathered for 7 days.	Polished. Heated to 150° for 4 hours.
1 F.C.	0·02	0·02	0·03
2 B.S.C.	0·02	0·03	0·04
3 B.S.C.	0·03	0·03	0·04
4 B.S.C.	0·02	0·02	0·03
5 H.C.	0·04	0·06	0·09
6 S.C.	0·08	0·26	0·23
7 L.B.C.	0·03	0·02	0·03
8 M.B.C.	0·04	0·04	0·03
9 D.B.C.	0·04	0·03	0·03
10 D.B.C.	0·03	0·03	0·03
11 D.B.C.	0·04	0·02	0·04
12 T.F.	0·05	0·02	0·04
13 L.B.F.	0·04	0·04	0·03
14 L.B.F.	0·05	0·03	0·04
15 L.B.F.	0·04	0·02	0·03
16 B.F.	0·03	0·02	0·03
17 E.L.F.	0·03	0·04	0·04
18 L.F.	0·02	0·02	0·03
19 L.F.	0·03	0·02	0·02
20 D.F.	0·03	0·02	0·02
21 D.F.	0·03	0·02	0·03
22 E.D.F.	0·02	0·01	0·01
40 F.C.	0·02	0·03	0·03
41 B.S.C.	0·03	0·04	0·04
42 S.C.	0·04	0·17	0·18
44 S.S.C.	0·05	0·25	0·24
45 L.B.F.	0·03	0·02	0·02
46 O.L.F.	0·03	0·02	0·03
47 H.F.	0·02	0·02	0·02

Evidently the alkalinity of polished surfaces varied very little for all glasses, except the soft crown No. 6. Weathering and heating resulted in deterioration in the lighter glasses Nos. 6, 42, and 44. The polished surfaces were less active than the fractured ones.

The Alkalinity of Fractured Surfaces Weathered under Varying Conditions.

The effect of weathering in dry air for seven days at 18° was tested. The heavier glasses, showing a decrease in alkalinity on weathering in moist air, gave a much smaller decrease in dry air, whilst glasses showing an increase still exhibited this change. Weathering in air free from moisture and carbon dioxide gave similar results, but the removal of carbon dioxide had a smaller effect, the dense glasses showing no change. Weathering in a vacuum over solid caustic potash and phosphoric oxide further inhibited the change which was most marked in case of the soft crowns. An increase in the temperature of weathering generally accelerated the rate of weathering. The soft crown glasses gave a continuously increasing alkalinity with a longer period, and higher temperature, as with increase of moisture, but the heavy glasses appeared to reach a steady state after heating for four hours at 150°.

The removal of moisture and carbon dioxide from the air in the heating experiments did not prevent the change in the alkalinity as much as at 18°. Hence, heat alone was capable of producing considerable rearrangement of the surfaces.

Influence of Chemical Composition on Alkalinity of Surfaces.

Although in Tables IA, IB, and IC closely analogous glasses gave similar results for the iodoeosin test, the complex composition of these glasses prevented any decision being formed as to the influence of any one constituent. Therefore, a simpler series of glasses was made and tested, the results being given in Table III.

TABLE III.

Molecular composition of glass.	Iodoeosin values. Fresh fracture.	Weathered fracture.	Percentage change in alkalinity.
$Na_2O,CaO,5SiO_2$	0·23	0·28	+22
$Na_2O,BaO,5SiO_2$	0·17	0·08	−53
$Na_2O,PbO,5SiO_2$	0·20	0·03	−85
$Na_2O,ZnO,5SiO_2$	0·12	0·08	−33
$K_2O,CaO,5SiO_2$	0·24	0·33	+37
$K_2O,BaO,5SiO_2$	0·19	0·06	−68
$K_2O,PbO,5SiO_2$	0·23	0·03	−87
$K_2O,ZnO,5SiO_2$	0·11	0·05	−55
$Na_2O,K_2O,2CaO,10SiO_2$	0·22	0·30	+36
$Na_2O,K_2O,2BaO,10SiO_2$	0·17	0·09	−47
$Na_2O,K_2O,2PbO,10SiO_2$	0·22	0·04	−82
$Na_2O,K_2O,2ZnO,10SiO_2$	0·13	0·06	−54

Calcium glasses gave greater alkalinity than lead, whilst the zinc glasses gave the least. In all cases except the calcium glasses a decrease in alkalinity resulted from weathering, being least with zinc glasses.

Durability as Determined Visually after Autoclaving.

The best comparative results were obtained by autoclaving polished specimens in water at 4 atmospheres (151°) for four hours. The plates were 3 cm. × 2 cm. × 0·5 cm. in size, polished on all faces. All specimens were cleansed, placed test surface uppermost in silver trays in covered silica dishes, and covered with water. The glasses after treatment were examined first by the naked eye, then more minutely under a microscope, and it was possible from the visible type of corrosion to discriminate between various optical types, and even to distinguish closely analogous glasses. Photomicrographs showed that the appearance of the corrosion depended more on the type of glass than on the duration of heating, a definite pattern being obtained for each distinct type. Borosilicates and hard crowns gave similar patterns, showing granular patches. Barium glasses gave very distinct patterns, a fine granular marking developing as the barium content increased.

With the lead glasses the effect increased with lead content, and the surfaces were covered with minute, opaque granules. Patches of the surface comparatively immune from attack were very noticable in the lead and barium glasses. Soft crown and fluor crown glasses showed marked attack, the surfaces of the former type being destroyed.

The Alkalinity after Autoclaving.

The alkalinity of the aqueous extracts was determined by iodoeosin. The loss in weight of the specimens was also determined.

From these tests it was clear that, under these conditions, the flint glasses were much more stable than the crowns, whilst the increase in lead content increased durability. Barium affected the resistance in the same way, but, on the whole, barium glasses were not as stable as lead glasses.

The heavier basic types were more stable than the lighter crowns, but the results had to be considered in conjunction with the chemical composition of the glasses before a definite measure of actual disintegration could be obtained. The alkalinity must be compared with the alkali content of the glasses.

In general, the losses in weight showed varying relations to alkalinity. A small loss in weight did not necessarily indicate slight attack, for, in the case of lead and barium glasses, much of the products of decomposition were left on the glass surface.

The Alkalinity after Autoclaving in Steam.

Polished and fractured specimens were heated for one hour at a pressure of 2 atmospheres (133°), but the great corrosion of the soft crowns and fluor crowns put them beyond the limit of this test. The alkalinity of the test surfaces was determined by iodoeosin.

Glasses 1, 6, 40, 42, and 44 were unsuitable for this test. The greater stability of polished surfaces was very marked, especially with the lighter glasses. In the case of barium and lead glasses, polishing would remove less of the soluble constituents than in soft crowns, or borosilicates; hence the polished surface would differ but slightly in composition from the mass of the glass, and polishing did not greatly affect the durability.

The order of glasses as arranged from these results was not in agreement with that resulting from alkalinity estimations of water extracts after autoclaving. This may have been due to the solubility of the decomposition products in the water exposing fresh layers of glass to attack, whereas, when autoclaved in steam, the products formed a protective coating. The results of the water test were considered more trustworthy than those of the steam test.

*The Dimming Test.**

Twelve British glasses were tested, and classified according to visible attack. The results were typical of the particular kinds of glass.

Retention of Moisture by Powdered Glass.

A number of British glasses were powdered, and the portions retained between meshes 90 and 100 were used. They were weighed, moistened with water, allowed to remain for a week, then dried in a vacuum. When constant weight was recorded the glass was heated to 120° until of constant weight. The moisture retained was expressed in mg. per 100 gm. of dry powder.

The results showed that, in general, the barium crown glasses retained the least moisture, the lead flints and barium flints coming next in order. The telescope flint retained more than dense or light flints, and the crown glasses retained considerably more than the heavier glasses. The borosilicate crown retained much less moisture in a vacuum, and gave it all up on heating.

In many cases, the dimming test and the test on powdered glass gave concordant results in the classification of the glasses.

The whole series of tests showed that a change in any of the conditions greatly affected the results. Hence, in order to obtain a true estimate of the durability of a particular glass a number of experiments under varying conditions had to be carried out.

It was not found possible to recommend one simple test which would determine precisely the durability of an optical glass under specific conditions in use. Moreover, considerable experience in making the tests was necessary. V. D.

113. Notes on Diagnosing Causes of Cords in Glass. F. Twyman (*J. Amer. Cer. Soc.*, 1922, **5**, 289).—The physical properties, such as refractive index, viscosity, and coefficient of expansion of cords generally differed from those of the mass of the glass. Methods for rapidly determining the relative values of these properties were described.

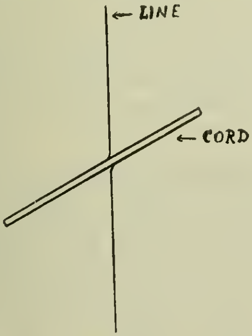


Fig. 82.

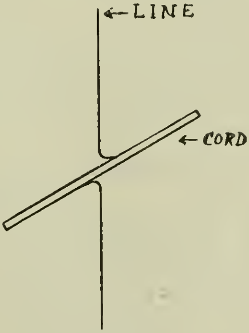


Fig. 83.

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* For details of test see this Journal, Trans., 1919, 3, 52.

Relative refractive index was determined by observing a straight line through the glass in such a way that the cord intersected the line obliquely. A cord of higher refractive index than the mass of glass caused distortion as in Fig. 81, whilst one of lower refractive index produced distortion as in Fig. 82. Immersion in a liquid of approximately the same refractive index would eliminate any such distortion arising from streak irregularity in the surface.

Relative viscosity was investigated by taking a cross-section along a cord, and noting its direction, especially whether or not it emerged from the glass surface. During the process of blowing, a cord flowed outwards, and when of lower viscosity than the mass of glass, it flowed over the mass at the surface, whilst the remainder of the glass flowed over it when it had the higher viscosity. This effect was well illustrated by photomicrographs, the cut surfaces of the glass being polished.

The relative coefficients of expansion in the neighbourhood of the annealing temperature were tested by observing, in polarised light, the direction of strain within the cord, whether it be a compression or an extension. Compression indicated a higher coefficient of expansion for the cord than for the mass of the glass.

Devitrification in a cord probably indicated that the cord was more liable to this defect than the remainder of the glass. It did not appear that cords could appear in a perfectly homogeneous mass of glass; for, in blowing and moulding an influence was at work tending to efface rapidly any differences of temperature. Thicker portions of the glass remained hotter and less viscous; hence they tended to become thin more rapidly, whilst a thinner portion got cool more rapidly, and was thinned out more slowly. Folds, however, might occur due to sudden chilling of a portion of the glass coming into contact with the mould.

Solution of an impurity, causing variations in the surface tension followed by movement of the impurity through the glass created a portion of slightly different composition and properties, and perhaps a cord.

In the discussion, Mr. G. W. Morey stated that cords of higher refractive index than the glass were rare, and were caused by insufficient mixing; also, crystalline material found within the cord was probably the cause of the cord, and could be identified optically as described by N. L. Bowen.* V. D.

114. Polymorphism and Annealing of Glass (Preliminary Communication). A. A. LEBEDEFF (*Trans. Optical Institute, Petrograd,* 1921, **2**, No. 10).—In searching for the best method of annealing optical glass tests were made which suggested that the effects on the physical properties of glass usually attributed to internal stresses were due not to these stresses but to a deeper structural change in the glass. Measurements of the refractive index of strongly hardened glass showed that the value might vary as much as 500 or more units in the fifth decimal place. A block of chilled glass was cut into small pieces and the refractive index

* *J. Amer. Cer. Soc.*, 1918, **1**, 594. Abstract, this JOURNAL, 1919, **3**, 13.

determined for fourteen samples. If the nature of the stress determined the variation of the refractive index the outer layers being in compression should have had a very different refractive index from the interior portions which were in tension. No such marked variations were shown, the departure from the mean value being only $6{\cdot}2 \times 10^{-5}$. In general the edge pieces had a greater refractive index than the others, but no definite connection could be established between the value of the refractive index and the position from which the glass was taken. On heating these fragments of glass to 570° and cooling slowly, the value of the refractive index was found to have risen 172×10^{-5} with mean departures of $\pm 5 \times 10^{-5}$, the compressed and extended portions of the glass having changed in a practically identical manner.

To determine the variation of double refraction with temperature, a block of glass was heated in an electric furnace, and the temperature gradient between the interior and the surface of the block was determined by means of differential thermocouples. The birefringence of the middle portion of the block was measured by Nicol prisms and a quarter wave-plate. It was found that the birefringence corresponded with the temperature gradient up to a temperature of 510°, but above that point, although the temperature gradient continued to fall, the birefringence suddenly increased, reaching a maximum at 560°, after which it decreased rapidly, and even changed the sign of the phase difference for a short time. Finally, all birefringence disappeared at 600°. The temperature gradient showed a little irregularity between 565° and 600°. These phenomena were explained by assuming that from 510° and upwards structural changes occurred in the glass and were accompanied by an expansion, and by an absorption of heat. The absorption of heat by glass at a temperature between 560° and 600° was confirmed by separate experiments using powdered porcelain or quartz glass as a comparison body, and measuring the difference of temperature by a silver–constantan thermocouple.

The variation of refractive index with rise of temperature was determined, using a modified Pulfrich method. Up to 520° the variation in refractive index was practically proportional to the temperature, rising temperature giving an increased refractive index. From about 520°, the refractive index began to fall rapidly, so that between 520° and 595° the fall amounted to as much as 300×10^{-5}, bringing the value of the refractive index lower than the value at the ordinary temperature.

Measurements of the variation of the coefficient of expansion with temperature showed that up to about 520° the coefficient of expansion changed slowly but regularly with temperature. Between 550° and 580°, a sudden increase was found. Beyond 580°, a rapid decrease occurred up to the point where softening occurred.

A suggested explanation of these anomalies was based on the assumption that they were caused by the transformation of α- to β-quartz. The anomalous behaviour always occurred in the temperature interval near 575°, which was the $\alpha \rightleftarrows \beta$-quartz transition temperature, and the character of the change in glass was always the same as was found in quartz. For example, Le Chatelier had shown that in changing from α- to β-quartz the volume increased about 2 per cent. Between 540° and 600°, the increase in the volume of glass was of the order of 1·5 per cent. Rinne and Kolb had shown that the transformation from α → β-quartz was accompanied by a decrease in refractive index of 400×10^{-5}, which compared well with the diminution of 300×10^{-5} found in glass.

According to this hypothesis, glass was supposed to contain very minute quartz crystals which probably contained other substances in solid solution, and the function of annealing appeared to be not so much the removal of stresses as the attaining of complete polymorphic transformation. S. E.

115. The Determination of Poisson's Ratio and of the Absolute Stress-variation of Refractive Index. F. Twyman and J. W. Perry (*Proc. Phys. Soc.*, 1922, **34**, 151).—The Hilger interferometer was employed for determining the stress–optical coefficients of a glass. Young's modulus of elasticity was determinable to within ± 3 per cent., and Poisson's ratio could then be found. The method was susceptible of refinement, and was applicable to other small variations in refractive index, such as variations of thickness and of mean refractive index from point to point of almost plane parallel glass plates. V. D.

116. On the Stress–Optical Effect in Transparent Solids Strained beyond the Elastic Limit. L. N. G. Filon and H. T. Jessop (*Proc. Roy. Soc.*, 1922, **101**, [*A*], 165).—When the stress in glass or celluloid which had been over-strained was released, a certain amount of residual illumination was visible between crossed Nicols in some cases. Experiments were carried out to test if such optical permanent set actually existed; and, in turn, to decide if stress or strain was the immediate cause of double refraction.

Test pieces were observed under simple stress (pressure in case of glass and tension in case of xylonite) between crossed Nicols. Sodium light was used, and changes of relative retardation were measured by the shift of the black band produced by a Babinet compensator.

Rectangular blocks of optical glass, of sp. gr. 2·76 to 4·78, were subjected to pressure between two knife-edges. The loads, reaching as near as possible to breaking point (150 to 200 kg. per sq. cm.), were applied for twenty-four hours or more, and the relative retardations ranged from three wave-lengths for lighter glasses, to one wave-length for the heaviest. The load was put on and removed quickly and smoothly and the retardation was measured within 0·01 wave-length. No increase in retardation occurred during the time of stress and no residual retardation was noted on removal of the load. It appeared, therefore, that the artificial double refraction in glass at the ordinary temperature was not dependent on any other factor than the stress actually applied.

Experiments made with celluloid proved the existence of a considerable initial effect on loading, followed by a creep. Initial recovery on unloading was roughly equal to initial effect, but the rate of creep on recovery was not the same. V. D.

III.—Lamp-worked and General Scientific Apparatus.

117. New Apparatus for Technical Gas Analysis. H. M. Lowe (*J. Soc. Chem. Ind.*, 1922, **41**, 11T).—A water-jacketed

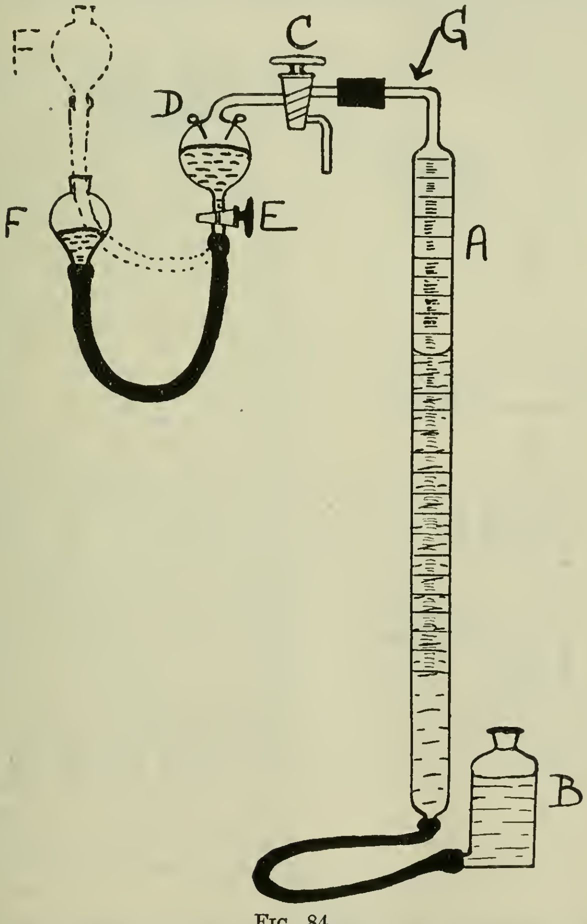

Fig. 84.

burette, *A*, of 100 c.c. capacity is filled with dilute sulphuric acid and connected with a levelling bottle, *B*. At the top it is permanently connected with a three-way tap, *C*, to the pipette of 200 c.c. capacity which in turn communicates through *E* and pressure tubing with the mercury reservoir, *F*. The sample of gas, or the absorbent, is drawn in through the open limb of *C*, and is expelled thence after use. The stock solution of pyrogallol can thus be made neutral, when it is relatively stable, and introduced into the pipette when the latter already contains the caustic soda from the previous absorption. The explosion is conducted with the mercury reservoir in the lower position and the tap, *E*, closed. If used on routine work for a single absorption, as, for example, in a determination of ammonia in waste liquor, a further three-way tap at *G* enables the burette to take the sample direct and a given volume of absorbent in the pipette serves for several estimations. M. P.

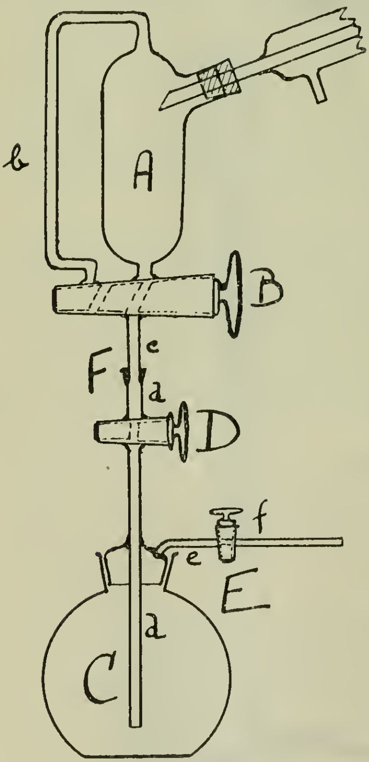

Fig. 85.

118. A Receiver for Fractionation in a Current of Gas, or under Reduced Pressure. T. S. Wheeler and E. W. Blair (*J. Soc. Chem. Ind.*, 1922, **41**, 59T).—The apparatus was designed to overcome the difficulties presented in collecting pure fractions in the older apparatus consisting of a large vessel with receivers mounted on a pivot capable of rotation. In such form the fractions were exposed to the vapour during the whole fractionation. In the new form this was not so. With tap *B* shut to *A*, but open between *c* and *b*, the distillate collected in *A*, whilst the gas supply (or vacuum) was maintained through the exit, *f*, of the tap *E*. The tubes, *c* and *d*, were drawn as for a heavy gas. The tap *B* was turned when a fraction had collected and the whole apparatus had been evacuated or swept out by the gas current, in order to put *A* in communication with *C*, and the liquid was sucked into *C*. *B* was then turned through 180°, *D* and *E* were shut, and the ground glass joint, *F*, opened. A new flask was put on and the second fraction collected in like manner after the air in it had been swept out by the gas current through *b*. M. P.

119. A Thermo-regulator. E. B. Starkey and N. E. Gordon (*J. Ind. Eng. Chem.*, 1922, **14**, 541).—The U-tube, *A*, is filled with mercury to the bottom of the capillary portion of the right-hand limb, and with the stopper, *F*, out, toluene is poured into the bulb, *B*, through *b* until the cross tube and the right-hand limb of the **U** above the tiny blob of mercury sealing the capillary is full. The stopper, *F*, through which is sealed a platinum wire extending to the bottom of the capillary portion, is then inserted and connected to the lamp, *D*, submerged in the bath, *C*. Current is fed to the lamp and to the other limb of *A* by copper leads. The bath is heated to the desired temperature with the tap, *E*, open, leaving the toluene free to expand above the tap. *E* is then closed and a further rise in temperature causes the expansion to drive down the mercury level in the right-hand limb of the **U**-tube, breaking the circuit. On cooling, contact is again made. The diameter of the capillary portion is 0·5 mm. and as the spark takes place in such a small volume of air the oxygen is very soon exhausted and so the fouling of the mercury is negligible. It is claimed that the bath may be kept steady to 0·05°. M. P.

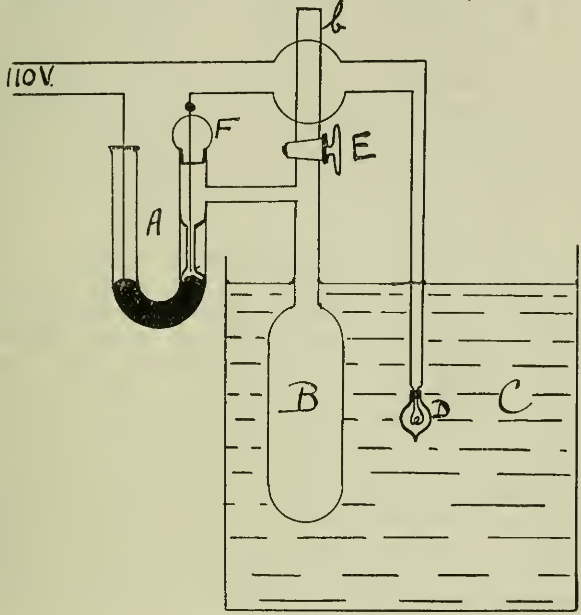

FIG. 86.

IV.—Decorated Glass.

120. The Manufacture of Artificial Fish Silver. O. PARKERT (*Sprechsaal*, 1921, **54**, 586).—Fish silver, used for decorating many kinds of glassware, such as pearls, was prepared exclusively in

France. These scales, obtained from certain kinds of fish, were shaken in a porcelain or enamel drum-sieve for a prolonged period with glass marbles, by which means the silver material was freed and fell into a vessel below full of water containing some alcohol and a few drops of salicylic acid solution. The washing was continued until practically all the silver substance was freed from the scales. At this point the washing solution was displaced by water, which itself was then removed, and the sediment allowed to stand for some time. A second washing was given with the mixture; water 45, alcohol 6, salicylic acid 5 parts. As so obtained, fish silver was very easily decomposed and became rotten, to remedy which fault it was mixed with water containing 1 per cent. of formalin and 7 per cent. of salicylic acid, and sold as pearl essence.

In the later war years, importation of the material into Germany practically ceased, and substitutes were sought. Aluminium powder was first used, and, mixed with gelatin or glue, it gave a greyish-white colour. On mixing the metal with powdered mussel-shell, a silver-grey powder was obtained, which, although an improvement, was yet not entirely successful. The same result was obtained by the use of a dilute silver nitrate solution with gelatin. The author had made a substitute from mica. Sheet mica was heated in a muffle for some time until it had a silver-white appearance. It was then powdered, mixed with gelatine or varnish, and directly applied or in the hot state was treated first with stannous chloride vapour, so producing an iridescent effect. Gelatin mixtures always produced a grey colour, but clear varnish gave a completely successful substitute for fish-silver. A treatment had been worked out whereby, by the use of chemicals, the artificial silver coating was given a mother-of-pearl appearance.

A. C.

121. Platinum Reflecting Surfaces Prepared by the "Burning-in" Process. J. Rheinberg ("The Making of Reflecting Surfaces," *Phys. Soc.*, 1920, 28).—The author found that a solution of platinum chloride in collodion evaporated very uniformly and yielded the requisite structureless permanent platinised mirror, but had to be heated to a temperature approaching the deformation temperature of the glass. A typical coating mixture consisted of: 3 volumes of 6 per cent. collodion in pure methyl alcohol, 3 volumes of platinum chloride in the form of chloroplatinic acid dissolved in industrial spirit, 3 volumes of industrial spirit and 1 volume of 1 per cent. bismuth chloride. The bismuth chloride stock solution was made by dissolving 5 per cent. bismuth chloride in industrial spirit with 5 per cent. hydrochloric acid and diluting this solution with industrial spirit as required. The addition of barium chloride to the solution lowered the temperature 30°, and was found to be satisfactory. There were four stages in the firing of such mirrors. The platinum was first loosely deposited by the evaporation of the collodion. The author suggested that it might be useful at this stage for making oscillograph or similar impressions as the deposit could be removed with a point. The impressions could then be made permanent; for, with a further rise in temperature the deposit adhered to the glass, being firmer than a chemical deposit. Further heating partly incorporated the platinum in the glass surface, and finally it was wholly incorporated and could not be scratched with a penknife, nor was it affected by any reagents which did not attack the glass. The depth to which the platinum penetrated was estimated at 200 $\mu\mu$, and consequently the layer was worn away if rubbed excessively. Hard crown glass, ordinary plate and sheet glass, and microscope cover-glasses had been successfully platinised. Flint- and barium-containing glasses were not suitable for this work. Test specimens should be platinised first in order to ascertain the correct firing temperature, which must be vigorously controlled. The method of working and polishing the glass affected this temperature, confirming the theory that the viscosity of the surface layer of polished glass was lower than that of the lower layers. The approximate firing temperatures for various glasses were as follows: optically worked hard crown, 620—650°; worked plate, 680°; unworked plate, 690—700°; sheet glass, 720°; quartz, 610—625°. The glass had to be kept at this temperature for three to five minutes. The process took longer at lower temperatures. The construction of the muffle furnace was described, the glasses being mounted on optically flat slabs of fused silica to prevent deformation. To clean the glass before platinising, it was immersed for twenty-four hours in nitric acid, washed in alcohol, wiped, and then heated for a short time at 200—300°. The reflecting power of platinised mirrors increased to a maximum as the amount of platinum incorporated in the surface increased. The author found that it exceeded that of a platinum surface, which reflected 56 per cent. of blue light and 70 per cent. of red light. The high reflecting power for infra-red rays rendered such mirrors suitable for pyrometers.

Experiments made to produce surface mirrors in this way, with metals other than platinum, were not successful except with other metals of the platinum group. Only these gave any approach to a neutral tint. J. R. C.

122. Note on the Silvering of Glass and Quartz Fibres. R. S. Whipple ("The Making of Reflecting Surfaces," *Phys. Soc.*, 1920, 21).—The Rochelle salt process was used, employing solutions consisting of (*a*) silver nitrate, 10 gm. in 1000 c.c. of distilled water and (*b*) silver nitrate 2 gm., Rochelle salt 1·66 gm. in 1000 c.c. of distilled water. The silver nitrate and the Rochelle salt were each dissolved in the minimum amount of water and added successively to the distilled water at the boiling point. The boiling was continued for twenty-five minutes, the solution filtered hot, and the filtering repeated if necessary. The fibres were drawn by means of a falling weight from a glass rod or tube of small diameter heated in an electric furnace. The rod was made free from grease before the fibre was drawn, and if the fibre was silvered on the same day no further cleaning was necessary. Apparatus for handling the fibres was described. J. R. C.

123. Mirrors Used for Perfecting Heat Radiation. C. Féry ("The Making of Reflecting Surfaces," *Phys. Soc.*, 1920, 24).—Metallic mirrors used in radiation pyrometers were specially liable to oxidation and sulphuration owing to the conditions under which they were used. There must be surface reflection at the metal in order to obtain a high percentage of the incident heat radiation. An endeavour to plate gold on bronze was not a success, because very small breaks in the gold deposit rapidly spread electrolytically. Silver deposited on glass and covered with a thin layer of Judee's bitumen reflected 97 per cent. of the radiation. Such mirrors did not show any selective absorption in the infra-red, could be cleaned by washing, and were cheap. The sources of Judee's bitumen were given in an editorial note. J. R. C.

124. Deposition of Metals by Cathodic Sputtering in a Vacuum. F. Ellerman and H. D. Babcock ("The Making of Reflecting Surfaces," *Phys. Soc.*, 1920, 25).—**The Production of Mirrors by Cathode Bombardment.** F. Simeon ("The Making of Reflecting Surfaces," *Phys. Soc.*, 1920, 26).—The technique of this method of making mirrors was explained in these two papers, the methods adopted differing only slightly in the arrangement of the apparatus. In both cases the discharge tube was evacuated until the Crookes dark space reached just to the face of the mirror. A current of about 0·02 amp. at 20,000 volts was employed. The method was not satisfactory for the production of mirrors exceeding 3 inches in diameter. J. R. C.

125. The Silvering of a Large Reflector. C. R. Davidson ("The Making of Reflecting Surfaces," *Phys. Soc.*, 1920, 18).—The Brashear process was modified for work at Greenwich; details were given of the composition of the solutions. In the case of very large mirrors, it was found to be most economical and convenient to make the mirror itself form the bottom of the bath. The arrangement for this was described. For a 30-inch reflector, 8000 c.c. of solution were required. To prevent the sediment, which always formed when the Brashear process was used, from settling on the mirror surface, the solution was kept constantly in motion. J. R. C.

126. The Silvering of Glass Reflectors by Chemical Deposition. F. Ellerman and H. D. Babcock ("The Making of Reflecting Surfaces," *Phys. Soc.*, 1920, 16).—An account of the resilvering of telescope mirrors at Mount Wilson Observatory. The Brashear process was used and, as usual, the reducing solution was made up at least one month before use. It increased in vigour and rapidity of action when kept for several years. For a mirror 5 feet in diameter, 80 fluid ounces of reducing solution and a proportionate amount of other materials were used. It was found

more profitable to use half the solution at a time and to apply a double coat. Directions were given for making up the solutions.
J. R. C.

127. Notes on the Formaldehyde Process of Silvering. H. N. IRVING ("The Making of Reflecting Surfaces," *Phys. Soc.*, 1920, 11)—Practical notes on the preparation of the solutions, the actual process, and polishing. J. R. C.

128. Some Workshop Notes on Silvering. J. W. FRENCH ("The Making of Reflecting Surfaces," *Phys. Soc.*, 1920, 12).—Five processes were considered, the author stating that the details might be obtained from Spon's book of recipes. The mercury–tin amalgam process could not be used for surface silvering, the side not in contact with the glass having a dull matt appearance. The formalin process was simple and rapid, but one deposit could not be laid on another and the deposits could not be electrolytically plated with copper. The Rochelle salt process had the advantage that it could be carried out at normal temperatures. The tartaric acid process yielded the best results only when the temperature of the bath was 40° and it was undesirable to submit finished optical parts to this temperature. In the author's view, the best method was Brashear's. Preliminary results on relative reflecting power showed that specimens silvered by this process reflected 98 per cent. of the incident light, against 90 per cent. for the tartaric acid process and 92 per cent. for the Rochelle salt process.

Brown stains were usually attributable to impurity of the chemicals and want of cleanliness. Pinholes in the surfaces, due to gas bubbles or to dust, gave rise to systems of concentric rings which gradually broadened. An unprotected silver layer tarnished quickly and must be protected as soon as possible. Saliva and perspiration accelerated the tarnishing. Experiments showed that even when the edges of the protecting varnish were sealed, surface silvering could not be protected sufficiently well for practical commercial use.

The cleansing of the glass surface was important. For the Brashear process, it was found satisfactory to clean the surface successively with naphtha, nitric acid, and ammonia, followed again by nitric acid and finally by distilled water. If a surface so cleaned was dipped into a solution of stannous chloride before using the Rochelle salt process, a more adherent layer was obtained. The brilliancy of the deposit was affected if a stannous chloride solution was used before silvering by the Brashear process.
J. R. C.

129. Survey of the Bibliography on Metallic Deposition on Glass. R. KANTHACK ("The Making of Reflecting Surfaces," *Phys. Soc.*, 1920, 1).—Liebig discovered in 1835 that when a mixture of aldehyde, silver oxide, and water was heated, the silver was deposited in the form of a mirror. Thenceforward the literature was chiefly a record of new processes, mostly based on Liebig's discovery. Petitjean in 1855, first used tartaric acid and Cimeg in 1861 Rochelle salt. Burton worked out a silver nitrate, caustic potash, loaf sugar, and alcohol formula in 1873 and Brashear's process, which dated from 1880, was a modification of this. A German patent specification had indicated the following drawbacks to present methods: great skill was needed; failures were frequent; silver was precipitated as soon as the solutions were brought into contact; only a small portion of the precipitated silver was deposited on the glass. To overcome the last two difficulties the glass was wetted with a silver nitrate solution containing formaldehyde and glycerine or other reducing agents. The wet plate was exposed to ammonia vapour or dipped into a solution of ammonia in benzol. A mirror was said to form instantly.

Most of the processes for gilding and platinising required furnace heat, but Rost's German patent of 1894 enabled platino-silvering to be carried out in the cold.

A bibliography of the most important papers between 1798 and 1915 on the construction and nature of reflecting surfaces was appended. J. R. C.

130. The Making of Reflecting Surfaces. (Discussion. *Phys. Soc.*, 1920, 39).—H. A. Hughes said that when it was desired to plate copper on a silver deposit it was more satisfactory to have a double coating of silver, thus obtaining a thick deposit. C. W. Davidson said that worked glass was silvered less readily than unworked glass. A. E. Le Rossignol, referring to the process of manufacturing mirrors by silvering a "form," copper-plating, and then stripping off the metal mirror so produced, said that this could be done by placing the "form," with the mirror attached, in a bath of warm water. A. F. C. Pollard had found that a glass surface, chemically cleaned, and then heated by a flame silvered more easily than one not so heated, possibly because some of the occluded gas was driven out. He also gave a recipe for gilding glass. This consisted of three solutions: *A*, 10 per cent. solution of gold chloride; *B*, 7 per cent. solution of caustic soda; *C*, two parts of alcohol through which coal gas had been passed for one hour, one part of pure glycerine, one part of distilled water. The mixture consisted of 5 parts of *B* and 1 part of *C*. This was diluted to 80 parts with distilled water and 5 parts of *A* were added. J. R. C.

V.—Optics and Optical Instruments.

131. Interferometers for the Experimental Study of Optical Systems. F. TWYMAN (*Phil. Mag.*, 1918, **35**, 49).—The instruments were designed for the correction, by retouching, of object glasses and prisms. This local polishing away of the glass was rendered necessary by the slight want of homogeneity of the glass of which the prism or objective was made. The instruments resembled the Michelson interferometer. In the first case, the prism was inserted in the path of one of the beams of light, and after passing through this the light was reflected back along its path by a plane mirror. In the second case, the light traversed the lens under test and reflection was accomplished by a suitable convex mirror. When the mirrors were adjusted, interference bands were seen which formed a contour map of the extent to which the passage of the beam twice through the prism (or lens) had distorted the wave front. The contour lines could be marked on one face of the prism (or lens) with a paint brush dipped in rouge, and the " hills " removed by local polishing. J. R. C.

132. An Interferometer for Testing Camera Lenses. F. Twyman (*Trans. Optical Soc.*, 1921, **22**, 174).—The interferometer described in the previous abstract had been modified so that the distortion due to the passage of non-axial pencils through the lens could be examined. The lens mount was altered so that the lens could be rotated about a line at right angles to the axis and passing through the second principal point. The reflecting mirror was simultaneously moved so that the light incident on it was always normally reflected. The adjustments necessary when the interferometer was used were described, and the interference pictures due to the usual defects given. J. R. C.

133. Graphical Methods of Correcting Telescope Objectives. A. O. Allen (*Phil. Mag.*, 1918, **35**, 471).—Formulæ and graphical methods for the production of small objectives were described. Reasons for employing them instead of extracting the curvatures directly from the N.P.L. tables were given. The methods were applied to a number of problems arising in the correction of objectives. J. R. C.

134. A Photometric Method of Measuring the Reflecting Power of Mirrors. J. W. T. Walsh (" The Making of Reflecting Surface," *Phys. Soc.*, 1920, 38).—The method and apparatus used at the National Physical Laboratory were described. The light from an electric lamp underwent three reflections at 45° and was compared photometrically with that from a standard lamp. No attempt was made to eliminate the light reflected from the glass surfaces, nor to correct for the absorption of the light by the glass. J. R. C.

VI.—Illumination and Illuminating Ware.

135. Process of Manufacturing Self-luminous Devices. R. W. Erdle, Assignor to Cold Light Manufacturing Co., Colorado (U.S.A. Pat., No. **1410741**, March 28th, 1922. Filed May 16th, 1918, No. 234849).—Reference was made to the very small size of some of the receptacles used for containing self-luminous substances, and to the consequent difficulty of filling them. This difficulty was overcome by drawing down a fairly wide glass tube until its diameter had been sufficiently reduced, cutting this narrowed portion, sealing the small end, and then filling in the self-luminous substance through the wide, funnel-like end. When sufficient had been filled into the tube it was cut and sealed in the usual way. S. E.

136. Metal Searchlight Mirrors. A. B. HUSSEY (*General Electric Review*, 1919, **22**, 652).—An account of the development of a metal parabolic mirror which could be used with large arc searchlights. A glass "form" was first made and polished on the outside to the required curvature. Silver was chemically deposited on this surface and the deposit thickened by silver plating. Copper was then plated on to the requisite thickness and this layer was covered by backing. The metal mirror was then removed from the glass "form" and came away in such a condition that polishing was unnecessary. J. R. C.

137. Glass Searchlight Mirrors. H. D. MINCHIN (*General Electric Review*, 1919, **22**, 660).—Such reflectors when in operation must withstand severe strains due to (*a*) heat from the light source, (*b*) transportation and handling, (*c*) shell-fire in the field. Metal reflectors had been largely used, but they quickly corroded. The difficulty with both metal and glass reflectors was to polish them with the necessary accuracy. A polished, concave paraboloidal surface was hard to obtain, and this had to be corrected because the source of light was not a point. To make the mirrors, a metal mould was first constructed, the convex surface of the mould being of the curvature required for the concave glass surface. The glass was melted in pots, poured on to a steel table and rolled, being then annealed. From the rolled sheets circular pieces were cut, free from stones, striæ, bubbles, etc. These pieces were placed on the moulds in an oven maintained at about 730°, the glass sinking to fit the mould, after which the glass was re-annealed by maintaining it at 730° for ten hours, cooling to 500° in forty-five hours, and thence to 370° at the rate of 13° per hour. When 370° was reached the oven door was opened and the glass allowed to cool steadily to atmospheric temperature.

The best forms of grinder and abrasive were still in doubt. Several methods were tried : (1) A wheel driven over the surface and guided by templates, abrasive being fed to the wheel at the point of contact. (2) An abrasive wheel driven over the surface in the same way. (3) Different forms of laps, varying from a strap to a complete shell. Laps were used for smoothing and polishing. Carborundum, emery, and sand were tried as abrasives. When polished on the convex surface (the concave surface was not polished apparently, but used as it came from the mould), this was cleaned and silvered, the silver being deposited upwards. The layer of silver was copper plated and the copper backed with several coats of paint. Between two of the coats a wire mesh was placed. The mirror was then baked in an oven at 90° for twenty-four hours.

The glass was inspected for flaws at all stages of its manufacture, and the finished mirror rigorously tested. In the first test, a cylindrical beam of light was projected parallel to the axis of the mirror and moved across it at right angles to the axis. The reflected beam should pass through a focus corresponding with the position of the arc in the searchlight; 0·375 inch tolerance was allowed. The reflection of a screen consisting of lines ruled to form squares was then photographed and the photograph examined for definition. A night illumination test was also carried out, the beam from the finished searchlight being examined for ghosts, or cones of light outside the parallel beam. J. R. C.

VII.—Fuels, Refractories, and Furnaces.

138. Producer Gas Plant Design. R. F. Clewell (*Glass Industry*, 1921, **2**, 283; 1922, **3**, 5, 33).—Factors to be kept in mind in installing producer plant were: (1) location, (2) capacity, (3) selection of equipment, (4) provision for future extension, (5) arrangement and accessibility of equipment for ease of operation and maintenance, (6) the gas distributing system. In addition, the fundamentals of simplicity and trustworthiness must not be overlooked.

It was easier to select a site for gas producers in modern factories where processes of manufacture lay in straight lines through the works than in older buildings where lay-out had been neglected. Where possible, the plant should be away from the factory proper to minimise the trouble of dust and soot, whilst hopper gates and openings for dumping dust in the system should be protected from the wind and provided with a water spray. The position of the plant should also be such as to give as short a distributing system as possible, and although producers should not be scattered indiscriminately it was often possible to reduce length of gas mains by distributing the producers in several units. Other factors governing location were practicability of coal storage and handling, and ease of ash removal, although it was better to have short distributing mains and a complicated coal handling system than long mains and simple coal handling.

Plant capacity was usually expressed as tons of coal gasified per twenty-four hours, that of single producers in the same way or often as lb. of coal gasified per sq. foot of fuel bed area per hour. The latter method gave figures independent of the size and type of producer. Hand-poked producers with average grade gas coal gave an average rate of gasification of 12 lb. of coal per sq. foot of fuel bed area per hour, and from this figure, with a knowledge of the amount of gas required for the furnace, the producer size could readily be calculated. Shells for hand-poked producers were obtainable of almost any dimensions, but the five or six well known types of mechanical producers were built for a fuel bed of 10 feet or 10 feet 6 inches in diameter. Mechanical producers, according to manufacturers' data, gasified approximately 38 lb. of coal per sq. foot of fuel bed area per hour or 36 to 40 tons of coal per producer per twenty-four hours. Intermediate types, with hand-poked producer shell but mechanical means for breaking and levelling the fuel bed, averaged 20 lb. per sq. foot per hour. The hand-poked producer figure was well within possible limits, but the other values were maxima and, for safety, a 75 or 80 per cent. factor should be employed. Three methods of determining approximately the limits of gas consumption for any furnace, with allowance for reserve capacity, were available. (1) Data for a new furnace similar to others already in use could be obtained by a study of the fuel consumption of the latter. (2) In replacing oil or natural gas by producer gas, the fuel value of the oil or natural gas was equated to that of the producer gas, allowing an average efficiency of about 75 per cent. for the producer system. Thus, to replace a daily supply of 1,000,000 cubic feet of natural gas of a heat value of 1,100 B.T.U. per cubic foot, by coal having an average value of 13,500 B.T.U. per lb., the number of tons of coal T* needed per day would be given by the equation: $1{,}000{,}000 \times 1{,}100 = 13{,}500 \times 0{\cdot}75 \times 2000 \times T$; or $T = 53{\cdot}4$ tons per twenty-four hours (4,525 lb. per hour). (3) From a knowledge of the design of the furnace, the weight of coal needed per ton of glass could be estimated. This method involved the calculation of radiation losses from the structure, as well as of the heat used in actual melting.

Sufficient reserve capacity should be allowed that if one unit was out of action, remaining units could carry the load. For a coal consumption of more than 100 tons per day high capacity mechanical producers should be installed; for 35 to 100 tons, semi-mechanical producers would be best; below 35 tons per day, semi-mechanical or hand-poked producers would be most advantageous. Each unit should consist of at least two producers, preferably of three or four, since disadvantages of single unit plants were: (1) lack of reserve capacity, (2) immediate effect of faulty gas production on the furnace, (3) complete dislocation on the breakdown of a single producer. On the other hand, it was more economical to have a few producers of large capacity than many low capacity producers.

Auxiliary equipment consisted of coal- and ash-handling systems, overhead coal bins, and regulators for maintaining constant gas pressure in the mains, and were all fairly standardised, but should all be chosen of sufficient capacity. Coal was usually passed from the crusher to bins over the producers by elevators and conveyers or by trucks (mechanically driven in the case of large plants). For ash removal, a push car under the producer with a skip hoist and bin outside the plant for discharge on to a railway wagon or truck, proved the best. Individual motor drive for each mechanical producer was better than the use of a common line of shaft.

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* Short tons.

Any lay-out of producer plant should take into account, as regards position and capability of extension, conditions likely to obtain in ten or twenty years' time. Points to be kept in view by the designer were, provision of suitable floor space on the firing floor, spacing of producers to admit of easy access to points below the firing floor, ample lighting and ventilation of the building. The centre line of the off-take from mechanical producers should not be more than four or five feet above the firing floor at any point, and there should be a sufficient number of clean-out doors to allow of thorough cleaning. Since the off-take for hand-poked producers was below the floor, the latter should be grated, and the pipe provided with blow-out holes for cleaning with steam. Off-take pipes should be connected to the common gas header by a two- or three-section elbow, and the header provided with a hopper under the incoming stream of gas, or, at the bottom, with an enlargement of the off-take into a hopper or dust leg at the connection. These precautions prevented solidification of dust and tar vapours on the sides of pipes or header. Rapid replacement of the agitator when worn was generally performed by suspending an I beam from the coal bunkers in a line over the agitator, and providing this beam with a trolley and chain hoist.

No satisfactory means had been devised for preventing the carrying of dust by the hot gas into the mains, and it was necessary to clean out the mains at intervals, generally each week. In hand-poked producer plants, this was performed by stopping gas production, opening up the main and connecting directly to the stack, so drawing air on to the soot and burning it, a process taking one to three hours. The process was more difficult in the case of mechanical producers, and it was usual to discharge the gas into a proportionally large area soon after leaving the producer, whereby the motion of the gas was almost stopped, whilst the heavy dust continued its path, preferably downwards, into a suitable hopper. The gas header itself could be made the settling chamber for several producers. In any case, some deposit was obtained along the mains to a distance of 300—400 feet from the producers, so that with short mains (for example, 150 feet) these should be of sufficient area to keep the gas velocity low, say not more than 10 feet per second, in order to prevent dust getting into the furnaces and choking up flues and regenerators. Openings at the bottom of the flues, provided with gas-tight doors, were servicable for removing the deposit in the case of mechanically poked producer systems, and these openings should be continuous, about 4 feet apart. Mains the bottoms of which were a continuous series of hoppers were now made. The total loss of pressure due to a flow of gas through a main was due to friction against the walls, resistance at elbows and bends, restrictions and enlargements, and to pressure changes caused by elevation. The two former were a function of the velocity of the gas; the last, due to elevation, amounted to + 0·01 inch of water column per foot of change of elevation. The following table gave calculated and observed pressure losses due to friction at varying velocities in a straight length of circular, brick-lined gas main 100 feet long, 13·7 sq. feet in area, and carrying producer gas at 1200° F. (calculated losses based on a perfectly clean main).

Velocity of gas in ft. per sec.	Observed pressure loss (inches of water).	Calculated pressure loss (inches of water).
12·5	0·03	0·024
18·4	0·06	0·052
20·6	0·08	0·065
22·1	0·09	0·075
25·0	0·12	0·095
27·7	0·14	0·116
44·5	0·38	0·290

Any design of main should allow that, with normal producer pressure (that is, not more than 2 inches head of water), sufficient gas pressure would be obtained at the furnaces. A table showing the rate of flow of gas in cubic feet per second at varying temperatures and for varying rates of gasification was given, from which, coupled with a knowledge of the velocity required to be maintained throughout the distributing system, the area of the mains could be determined. Gas mains should be insulated, since otherwise heat radiation losses were very great, and tar also settled out through chilling of the gas, the latter effect occurring in mains more than 150 feet long. A. C.

139. The Microscopic Examination of the Mineral Constituents of some American Clays. H. G. SCHURECT (*J. Amer. Cer. Soc.*, 1922, **5**, 3).—American clays had been found which approached the English china clays in fineness of grain, plasticity, shrinkage, dry strength, and colour, but still the clays from the two countries behaved differently when applied commercially. In endeavouring to explain the causes of the differences the author undertook a microscopic study of the differently sized grains of a number of clays in order to determine qualitatively the mineral constitution and physical character of the grains. The English china clays consisted mostly of distinct crystalline plates and plate-like aggregates of *kaolinite*, whereas Georgia and South Carolina clays were constituted largely of "colloidal" kaolin aggregates. Clays constituted of crystalline plate-like grains and aggregates as compared with those made up of colloidal aggregates showed a much lower adsorption, and would therefore disintegrate more rapidly in the blunger, require less water to place them in a plastic condition for jiggering or fluid condition for casting, give up water more readily to the plaster mould, and develop less drying strains. A microscopic study of the clays fired at 1000° frequently showed what minerals were responsible for undesirable colours obtained and served to indicate how such clays might be improved by better refining methods.

The method used was to separate each sample of clay into nine different grain sizes by screening and elutriation and to examine each size separately under a petrographic microscope. The oil immersion method was used for determining the indices of refraction for identifying the minerals. The different grain size portions were then fired at 1000° and their colour noted by comparison with standard colours, and the minerals causing undesirable colours examined under the microscope.

The minerals found present in the clays were chiefly *muscovite, quartz, tourmaline, biotite, zircon, alkali felspar, plagioclase, rutile,* hydrated silica, and *hæmatite.* The objectionable abrasive features of American clays causing excessive wear to machinery could be readily overcome by more careful refining methods, but it was impossible by any known methods or process to transform the colloidal *kaolinite* particles of the American transported clays into the crystalline, plate-like structure of the English china clays.

Fourteen tables were given containing the detailed results of the examination of the various clays. F. W. H.

140. Cleaning Producer Gas without Washing. J. H. Matheson (*Iron Age*, 1922, **109**, 916).—A very effective cleaning of raw producer gas was effected by providing soot pockets at the bottom of the uptake and downtake flues leading from the producer. By this device also, the gas of several producers was mixed and made uniform. The several passages from the producers communicated, near the bottom, into the uptake (Fig. 87). In each passage was a damper of the usual form for closing the individual producers. The downtake flue connected by a horizontal

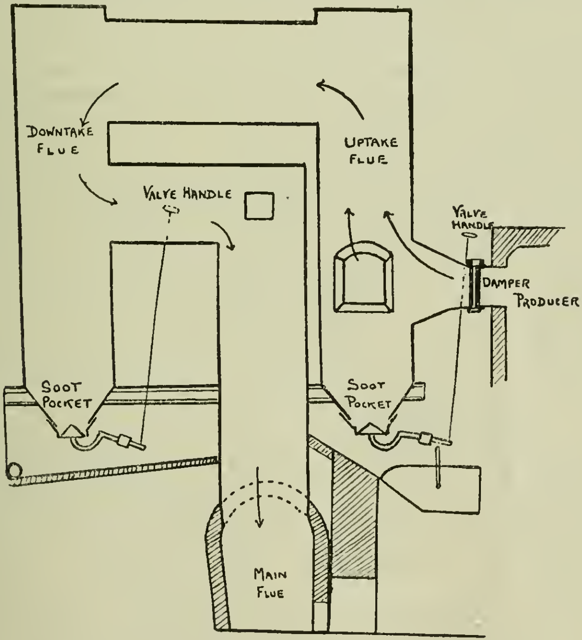

Fig. 87.

passage with the uptake flue at the upper end. From the downtake flue, gas passed across to a second vertical flue leading to the main flue below the ground level. The bottom of both uptake and downtake flues was tapered to a valve by which soot could be readily removed. Each side passage had also a soot pocket with a bottom bevelled toward the opening, which was closed by a hand operating valve. The uptake and downtake flues were rectangular in section, so providing large surfaces on which the gas could impinge to facilitate mixing of the gas and separation of the soot.

With such a device cleaning of the main flue was obviated. It was claimed that 20 to 25 per cent. of the fuel was, in this manner, saved, and simplicity of building and working were obtained.

A. C.

141. The Plasticity of Clays. F. P. Hall (*J. Amer. Cer. Soc.*, 1922, **5**, 346).—A discussion of the term "plasticity" and of the methods used for measuring this property of clays. Methods based on the bonding power of the dried clay were not considered, as the bonding power of the dried clay was regarded as quite a distinct property. With most methods, it had been found very difficult to obtain satisfactory and concordant results, owing to the heterogeneity of clay–water. The consistency of such a mixture was influenced by several factors, namely, (1) past history of the clay, (2) type, (3) amount of working received, (4) time of contact of clay and water, (5) temperature of mixture, (6) amount of water. The inability to control some of these factors rendered it difficult to obtain satisfactory results.

In the Ashley dye-absorption method, the plasticity was assumed to be inversely proportional to the grain size, and the absorptive power of clays for dyes was measured, with the view of determining the colloidal content. As all clays do not contain the same colloids, and all colloids have not the same absorptive power, the method was not considered satisfactory by the author.

The Stringer-Emery method gave difficulty in the preparation of a spherical test-piece, and the units were empirical. It was found that the greater the plasticity, the greater was the proportion of water to be added to develop the maximum plasticity. A ball clay required 30 per cent., a kaolin 20 per cent., and a very *short* clay required only 10 per cent. of water to make it sticky.

The MacMichael torsional viscosimeter, an instrument for determining the viscosity of liquids, was found to be unsatisfactory for use with plastic substances, such as clay slips, as the local agitation set up within the outer cylinder changed the apparent wetness of this part of the slip.

The Emley plasticimeter (Bureau of Standards Tech. Paper, No. 169) measured the property of retaining water, and the resistance to deformation under pressure, of a substance, but not the plasticity as understood by ceramists.

The Attenburg plasticity method, based on the varying physical behaviour of clays with different water content, left too much to the judgment of the individual, but might be of use for comparative tests. The range of water content over the workable stage was determined, the washable stage being decided arbitrarily, and extending from a point at which the clay would barely flow, to a point at which the mass could no longer be rolled into threads. The wider this range, the more plastic the clay.

The Bingham plastometer, an instrument by means of which the rate of flow through a capillary tube, under a definite constant head of pressure, was measured, was found to give more satisfactory results for clays. The plastic state necessitated a definite pressure before the substance would flow, and this initial friction value differentiated the plastic from the viscous state. The initial friction value, or the yield value, and the mobility of a clay were used to define plasticity roughly. Having determined by means of the plastometer the mobility and yield value of one clay, a second clay was taken, the water content varied until the mobility was the same as for the first clay, using the same capillary. The flow at several pressures through the capillary was determined, then the volume discharged per second was plotted against the pressures, the relation being linear. The yield values were given by the intercepts of the graphs on the pressure axis, and, the mobilities being equal, the plasticities varied directly as the yield values.

None of the methods considered was wholly satisfactory, the greatest difficulty appearing to be the defining of the term plasticity, and the ability to keep to the definition when attempting to measure it. V. D.

142. Porosity. VI. Determination of Porosity by the Method of Gas Expansion. E. W. Washburn and E. N. Bunting (*J. Amer. Cer. Soc.*, 1922, **5**, 112).—The pore volume was determined by allowing the gas which filled the pores to expand into a measured volume and measuring the accompanying fall in pressure. The method was generally applicable to pieces of any size and shape and to all classes of porous bodies or materials.

A flask or other suitably shaped vessel, *B*, of volume V_1, was joined, by a capillary tube carrying a stop-cock, to the test vessel, *A*, of volume *V*. To the vessel, *A*, was also attached a suitable manometer, *M*, for measuring the pressure. The weighed piece or sample (*W* grams) of the dry material was placed in vessel *A* and, if maximum accuracy was required, the remaining unfilled portion of vessel *A* was filled with glass beads or rods of density D_g and mass m_g. The pressure in the vessel *A* was then reduced (for example, to 20 mm. of mercury).

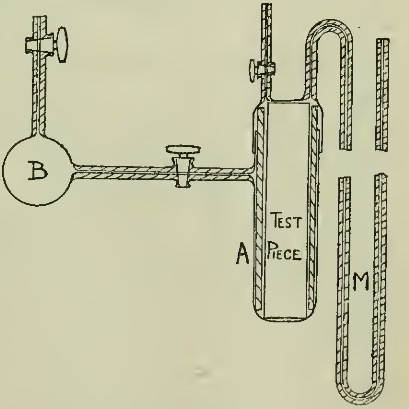

Fig. 88.

Flask B was filled with a non-adsorbable gas under suitable pressure. For most ceramic bodies dry air was satisfactory, but hydrogen would be required in some instances. Helium could be employed for all types of porous materials at room temperatures or above. If a gas other than air were used, the vessel A and the pores of the material under investigation must first be filled with this gas before evacuating the vessel A to the pressure P_0.

The whole apparatus was now allowed to stand (preferably in a constant temperature bath, if maximum accuracy were desired) until temperature equilibrium was attained. The vessel B was then opened momentarily to the atmosphere in order to secure atmospheric pressure within it, and was then closed again. When complete temperature equilibrium was attained the manometer was read (P_0) and the stop-cock connecting the two vessels was then opened. When equilibrium was again attained the manometer was read (P). The percentage porosity x could then be calculated from the relation (B in formula=barometric pressure)

$$x = 100\left[\frac{(B - P)V_1}{(P - P_0)V_B} - \frac{V - m_g D_g - V_B}{V_B}\right]$$

The bulk volume V_B, if not determined directly on the sample or piece used, was calculated from the relation $V_B = \frac{W}{D_B}$.

The functioning of the manometer should not appreciably affect the volume of the vessel to which it was attached or else the necessary correction should be applied. The method could be used with the manometer attached to either vessel and, if desired, the evacuation might be applied to vessel B instead of to vessel A.

The best volume for the vessel B was that given by the expression

$$V_1 = \frac{100(V - m_g D_g) + (x - 100)V_B}{100}$$

and under those conditions $P = \frac{B + P_0}{2}$.

For a given size of test-piece the accuracy of the measurement increased as the unfilled space in vessel A decreased. This was the reason for filling the space around the test-piece with glass rods or beads as far as possible.

If the volume measurements were accurate to 0·01 c.c. and the pressure measurements to 0·2 mm. of mercury, the total error in x would not exceed 0·1 unit for porosities up to 30 per cent. and would not exceed 0·2 unit for higher porosities. Greater accuracy could be secured, if required, by proper design and care in measurement. A variation of 0·5° in temperature between the initial and final pressure readings would produce an error of only about 0·1 unit in the computed porosity provided P_0 was not greater than about 20 mm. of mercury.

Far rapid work with shaped test-pieces a new porosimeter was described. The instrument measured accurately both pore volume and bulk volume. A complete porosity determination could be made in five minutes. No weighing was required. The results obtained were reproducible to one unit in the first decimal place of the percentage porosity and considerably greater accuracy could be obtained if desired.

Results for porosity obtained by the gas-expansion method were in all cases higher, in a number of cases much higher, than those obtained by the methods of liquid absorption in current use. For fired bodies, the same results were obtained with dried air, hydrogen, or helium as the pore filling gas. The results showed conclusively that complete filling of the pores in a reasonable time could not be secured by any of the current methods, using a liquid as the pore filling agent.

The advantages of the gas expansion method were that (1) it would give correct results even in the case of bodies containing a very considerable volume of micropores with narrow openings, (2) it was not necessary to dry or to weigh the test-pieces at any stage of the process, (3) in its general form the method was applicable to bodies of any size and shape (including granular material), provided the bulk volume or bulk density of the body or material was known or could be determined, (4) since the method employed no pore filling liquid it did not injure or alter the test-piece or material in any way, (5) in its rapid form the method was sufficiently accurate for all practical purposes. If a number of test-pieces had to be examined the average time consumed in a complete determination of the porosity was, per test-piece (*a*) two to three minutes for an accuracy of one unit in the result, (*b*) five to ten minutes for an accuracy of 0·1 to 0·3 unit in the result, (*c*) the method seemed to be entirely suitable both as a practical engineering method and as a standard reference method for all classes of bodies. F. W. H.

143. The Handling, Storing, and Setting of Glass Pots. Wm. M. Clark and J. H. Forsyth (*J. Amer. Cer. Soc.*, 1922, 5, 146).—If pots were carried by rail they should be put in a covered truck, set on dry straw, and well braced to avoid slipping or jarring. All tackle used for removing pots from trucks should be well padded with strips of canvas or rubber hose. It had been found advantageous to have spring suspensions and roller bearings to avoid jolts when crossing thresholds, rough flooring, and other irregular surfaces. All straining, jolting, and jarring should be eliminated wherever possible. The usual precautions in storing were indicated, and for setting it was recommended that the size of the furnace be carefully prepared to insure an even distribution of load on the bottom of the pot and to make certain that the pot was either level, or tilted slightly forward. F. W. H.

144. Pots used in Optical Glass Manufacture. R. J. Montgomery and M. R. Scott (*Glass Industry*, 1922, 3, 91).—Quite recently the authors experimented on almost all types of pots on the market, and found two makes of pot far superior to all others. The production of optical glass, however, necessitated a still better pot. The batches and method used by the authors to obtain improved pots were based on work done at the Bureau of Standards by Dr. A. V. Bleininger, and the new type of porcelain pot, produced either by the casting process or by hand, gave better results with corrosive glasses than the older fireclay pot. The analyses of two raw fireclay pots were as given below, and these were about the extreme in composition.

	High silica type.	Low silica type.
SiO_2	74·05	60·05
Al_2O_3	19·14	31·70
Fe_2O_3	1·66	2·91
TiO_2	1·00	0·40
CaO	0·19	0·34
MgO	0·32	0·50
K_2O	0·44	0·44
Loss on ignition	4·30	4·50
Total	101·10	100·84

The most suitable amount of silica which a clay should possess was still unsettled, some manufacturers claiming that a highly aluminous pot was less liable to attack, owing to the formation of *sillimanite*. Pit holes, however, might form in such a pot, and allow particles of comparatively insoluble clay to float out into the glass, causing stone.

The porosity of a pot might vary from 20 per cent. at the centre of the bottom to about 5 per cent. at the rim, and an open structure allowed of rather sudden temperature changes due to cold batch, changes in furnace temperature, and taking the pot out for casting glass. When experimenting on the newer porcelain pots, both the clay casting process and the old hand method were employed, although in some cases the same batches were used. Kaolins, flint clays, and ball clays of low iron content were selected to replace the fireclay, and 5 to 10 per cent. of felspar was added to increase the density of the hand made pots. The iron oxide content was reduced from 2·0 per cent. to 0·7 per cent. The porosities and the densities of the porcelain pot and the fireclay pot were given as below.

	Porcelain pot.		Fireclay pot.	
	1	2	1	2
Porosity :				
Rim	2·61	1·13	9·28	13·70
Belt	2·39	1·85	10·92	18·25
Knuckle	1·82	1·82	14·21	13·99
Bottom	6·37	3·52	17·45	19·08
Apparent specific gravity :				
Rim	2·08	2·15	2·33	2·53
Belt	2·06	2·15	2·36	2·54
Knuckle	2·09	2·18	2·38	2·55
Bottom	2·22	2·28	2·45	2·60

The porcelain pot containing 2·5 per cent. of alkali was not as refractory as the fireclay one containing some 0·5 per cent.; it was more brittle, and liable to air check when taken out to cast glass, but it would withstand a melting temperature of 2580—

2600° F., and three or four trips to the casting table. Hence it would meet the needs of optical glass production.

The reduction or elimination of the felspar gave a more refractory pot of more open structure, and this pot had a low iron oxide content.

Pot attack by glasses containing say from 30 to 50 per cent. of barium oxide, and from 50 to 65 per cent. of lead oxide, seemed to depend more on density and uniformity of structure than on small changes in chemical composition. These glasses would entirely penetrate, at melting temperatures, through a pot of porosity 20 per cent.

When casting porcelain pots, sodium silicate and carbonate were added in about equal quantities to produce a slip containing approximately 20 per cent. of water. The amounts used were some 0·2 per cent. of the dry weight of the clay. In this way, the density of the pot was increased and its refractoriness decreased The following table shows the differences for a semi-porcelain pot cast, and hand made, using the same clay batch.

	Hand made pot.		Cast pot.	
	Porosity.	App. specific gravity.	Porosity.	App. specific gravity.
Rim	6·69	2·33	3·49	2·19
Belt	13·78	2·43	6·98	2·27
Knuckle	14·65	2·45	12·20	2·36
Bottom	18·80	2·49	13·82	2·36

The hand-made pot would stand a furnace temperature of 2600° F., whilst the cast pot could not be used above 2525° F.

The increased density, uniformity, and low iron oxide content of the porcelain pots made them more suitable for optical glass production than the more refractory fireclay pot, but great care was necessary in making cast pots to select a batch that was sufficiently refractory, and yet had the desired density. V. D.

145. Physical Defects in Tank Blocks. G. A. Loomis (*J. Amer. Cer. Soc.*, 1922, **5**, 102).—Blocks were selected at random from carload shipments of each of three makes. One block was likewise taken from a small shipment of another make. These blocks were carefully cut up into sections about 3 inches thick by cutting all around the block with a broad chisel until the section became detached from the balance of the block. In all but one or two cases these sections were removed intact. Whenever a loose " sliver " remained attached to the section, it was carefully removed to avoid mistaking it for an imperfection. The sections were then carefully examined and photographed.

Examination showed that physical defects were present to an objectionable extent in all but one of the makes examined. All the blocks of one make showed a total absence of fissures, laminations and other defects and this would appear to indicate that it was possible to produce tank blocks entirely free from such defects.

F. W. H.

146. Physical Defects in Tank Blocks. W. A. McIntyre (*Bull. Amer. Cer. Soc.*, 1922, **1**, 54).—A contribution to the discussion of the paper by G. A. Loomis (*J. Amer. Cer. Soc.*, 1922, **5**, 102). Photographs were reproduced showing defects met with in practice. In a typical case there were visible concentric laminations, gradually flattening out and becoming almost horizontal, in addition to cavities and irregularly arranged pinholes. In the preparation of microscopic sections of blocks it was found that they tended to fracture very readily in the direction of trend lines and this peculiar structure seemed to persist throughout the blocks.
V. D.

147. Procedure and Apparatus for the Protection of Tank Blocks from Attack by Glass Gall. C. Jung (Czecko-Slovakian Patent No. 4438/1920; *Sprechsaal*, 1921, **54**, 541).—Attack on tank blocks was prevented by the use of several large fireclay rings floating in the glass at the melting end of the furnace. Batch was filled into the rings in turn so that glass gall was confined to the interior of the rings, whilst the laying of fresh batch on batch not yet melted was prevented. A. C.

148. The Effect of Weather on the Strength of Refractory Brick. R. M. Howe, S. M. Phelps, and R. F. Ferguson (*J. Amer. Cer. Soc.*, 1922, **5**, 107).—The bricks under observation were piled on the ground about ten high in a wire pen which was open at the top and protected only on one side. Samples were reserved for testing and the rest were stored for three-, six-, nine-, and twelve-month periods. Care was taken to secure specimens, at the expiration of these intervals, from the top, centre, and bottom of the pile. Cold crushing tests were applied to each set of samples, selecting from six to eight bricks in each case. Spalling tests were made on fireclay bricks by heating the samples in the door of a furnace operating at 1350°, partly immersing them in a trough of running cold water for three minutes, air drying, and repeating in hourly cycles.

The crushing strength of magnesia bricks decreased 15 per cent. in six months and 33 per cent. in twelve months. The silica bricks showed no outward sign of deterioration, but lost 39 per cent. of their original strength during the twelve-month period. The fireclay bricks lost from 1 to 21 per cent. in cold crushing strength after six months, and from 11 to 28 per cent. after twelve months. Machine-made, very strong firebrick, showed practically no loss of strength after six months' exposure, but some open, porous, hand-made bricks having an end crushing strength of only 500 lb. per sq. inch were practically worthless after six months' storage.

The spalling of firebrick was increased by 20 per cent. after exposure for twelve months. F. W. H.

149. Tank Furnace Construction. H. J. Travis and Corning Glass Works (U.S.A. Pat., No. **1410782**, March 28th, 1922. Filed November 19th, 1920, No. 425120).—The bridge of a tank furnace consists of a refractory cylinder, 16, secured to the side walls of the tank and provided with an axial bore for the circulation of cooling air.

The cylinder is built up of refractory tubular blocks placed end

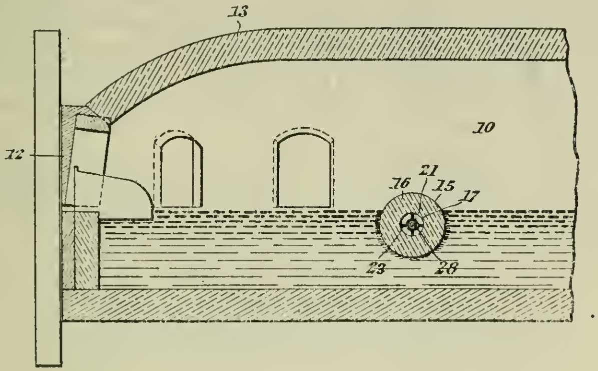

FIG. 89.

to end and interlocking with one another, a tie rod through the centre serving to keep the blocks together. A pipe, 21, is passed through the bore and is formed with radiating pins, 23, to act as supports for the blocks. Air is blown through the pipe and through the space separating it from the blocks. The cooling action of this air freezes a coating of metal on the blocks, strengthening them and protecting them from solution in the metal. G. D.

150. Silicate Cements. W. CARPMAEL, London, and F. BAYER & Co., Germany (Brit. Pat., No. **168659**, June 4th, 1920).—Cements for dental and other purposes consist of a base such as magnesium or beryllium oxide mixed with a solution of a hydrolysed organic silicon compound, containing a high percentage of silicic acid. The organic silicon compound, for example, tetramethyl silicate or a condensation-product thereof, may be hydrolysed by water or dilute acid, either alone or in the presence of phosphorus pentoxide or an alcoholate of an alkaline-earth metal or of magnesium or of aluminium, or both. Examples of proportions are given. H. G. C.

151. Carborundum Facings for Fireclay Bricks. CARBORUNDUM CO., LTD., Manchester, and S. C. LINBARGER, Niagara Falls, New York, U.S.A. (Brit. Pat., No. **168261**, September 25th, 1920).—Firebricks and other refractory articles having a body portion, 4, consisting substantially of fireclay are provided with a facing portion, 2, containing more than 50 per cent. of silicon carbide, and one or more intermediate layers, 3, containing silicon carbide in proportions decreasing from the facing layer inwards. In making the articles, the different compositions are successively introduced into the mould, the surface of each layer being roughened before the addition of the next layer. H. G. C.

152. A Small Glass Tank (Furnace). H. T. Bellamy (*J. Amer. Cer. Soc.*, 1922, 5, 157).—A cross-section of the furnace was shown as in Fig. 90. It was built for the manufacture of lead glasses (instead of small pot furnaces) and had successfully melted high lead crystal, alabaster, opal, gold ruby opalescent, and green opalescent glasses. An output of about 500 lb. per day was desired and the melting chamber was devised of the desired capacity with standard tank blocks. The initial cubic content was about 4·5 cubic feet with a depth of 7 inches.

The fuel used was uncarburetted blue water gas which was boosted to a pressure of 10 to 12 lb. by a water-sealed pump. A valve and gauge at each of the three burners controlled the distribution of the gas. As the gas passed through the burner nozzle into the throat at a high velocity, the pressure energy was transformed into velocity energy and air was induced into the throat through an adjustable shutter. The gas and air mixture then went through a Venturi tube to facilitate thorough mixing before passing on to the burners. The burners were inclined at an angle of 30° from the horizontal so that the flames would brush against the arch.

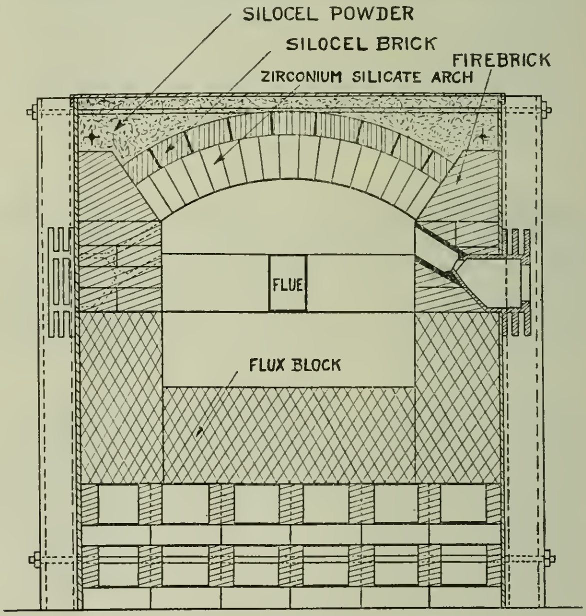

Fig. 90.

The time required to bring the furnace up to melting temperature was four days when new, but thereafter the furnace could be cooled off and reheated up at the week-end without greatly increasing the depreciation. This feature was quite an advantage in the making of glass periodically.

The first arch, built of silica bricks, spalled badly and cracked on heating up. The silica bricks were replaced by an arch of zirconium silicate bricks, laid in zirconium silicate containing about 5 per cent. of clay. This arch had been in service for about a year and was still in very good condition. When it was necessary to replace corroded tank blocks, the arch was removed brick by brick so that they might be set up again. This was possible because there was no fluxing of the bonding material or the brick.

F. W. H.

153. Water-cooling Device for Furnace Walls. R. L. FRINK, London (Brit. Pat., No. **169304**, July 2nd, 1920).—The walls of a glass-melting tank furnace are cooled by water directed on to metal plates, 1, having good thermal contact with the wall. The water is delivered from a perforated or slotted pipe, 3, at the upper edge of the plate on to an inclined baffle, 4, having an indented edge in contact with the plate; or, if fine perforations can be used, the baffle is dispensed with. As a further alternative the water may be allowed to overflow from an open trough on to the baffle, 4. The water collects in an open channel, 6, at the lower edge of the plate. H. G. C.

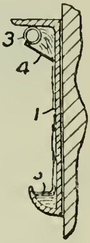

FIG. 91.

154. New Arrangement of Ports in Glass Furnaces. R. L. FRINK, London (Brit. Pat., No. **169789**, July 2nd, 1920).—In a gas-fired tank glass-melting furnace, a special arrangement of ports, etc., is provided to minimise reducing action on the metal. Gas from adjacent producers, 10, enters at both sides through a number of transversely-directed ports, 3, and meets heated air rising in passages, 1. Preliminary combustion takes place in chambers, 6, and the burning gases then pass longitudinally along the furnace chamber into the working chamber, 11, which they leave immediately through ports, 8, directed rearwardly and transversely of the inlet ports. The air is supplied in excess, and owing to this and to the arrangement of the air ports, 1, and also to the rapid removal of the gases from the working end, 11, contact of reducing-gases with the metal is avoided. The hot-gases, after leaving the furnace, pass through regenerators, 2. H. G. C.

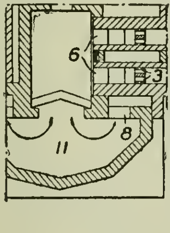

FIG. 92.

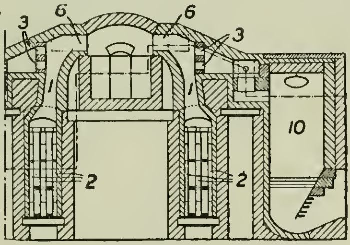

FIG. 93.

155. Glass-annealing Furnaces. R. L. FRINK, London (Brit. Pat., No. **169537**, July 2nd, 1920).—In a tunnel glass-annealing lehr, the muffle heating chamber, 1, is constructed of corrugated cast-iron plates, preferably with high silica and low carbon content, and the walls of the cooling-portions, 1*a*, 1*b*, etc., are of different thicknesses, so that a desired graduated temperature drop is attained. In the heating-portion, the combustion chamber, 2, is above the muffle, and gaseous fuel and air are introduced at 3. Vertical flues, 4, lead to bottom flues, 5, and to a central outlet, 9*a*, to the regenerator, etc. The flues, 4, are at the back and front alternately, so that half the gases pass in one direction round the muffle and half in the other direction. The first cooling-portion, 1*a*, is built of brickwork, etc., and the remaining portions of metal plate with an external coating of asbestos, etc., which is thinner towards the outlet and may be omitted on the last section, 1*d*. H. G. C.

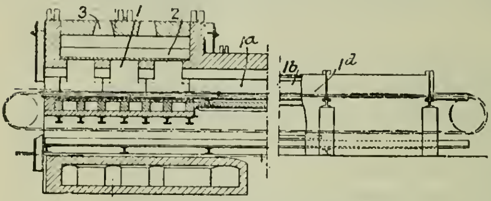

Fig. 94.

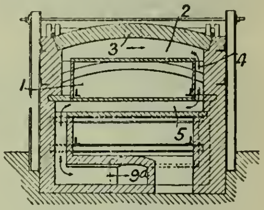

Fig. 95.

156. Improvements in Recuperative Glass Furnaces. W. J. Mellersh-Jackson, London, and Stein et Cie, Paris, France (Brit. Pat., No. **169595**, August 17th, 1920).—A crucible glass-melting furnace of the type operated by the Siemens process having recuperators and heated by gas consists of two opposed vaults or combustion chambers, 5, connected by a passage in the centre of which the burner, 1, is situated. The burner is supplied with gas by a flue, 2, and with hot air from recuperators, 15, by

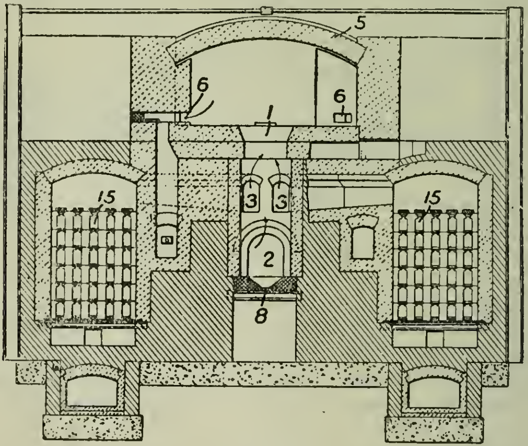

Fig. 96.

flues, 3. Crucibles are placed in front of outlet ports, 6, in the sides of the vaults, each port communicating with a separate recuperator. An outlet, 8, is provided for the escape of molten glass if a crucible should be broken. H. G. C.

157. An Automatic Lehr. E. H. Curtis (U.S.A. Pat., No. **1386240**, August 2nd, 1921. Filed December 24th, 1917, No. 208889).—A device for conveying articles through a lehr consists of closely interspersed fixed and movable bars which form the floor of the lehr, and of means automatically controlled for slowly moving the movable bars above and below the fixed bars, and forwards and backwards in short steps of a length adapted to clear one row of articles from the next succeeding row whereby the articles are slowly moved through the lehr. The device is thus somewhat similar to the well-known device used in sheet glass lehrs, but by closely spacing the bars and by slow movement, the device is made suitable for use with bottles and tableware.

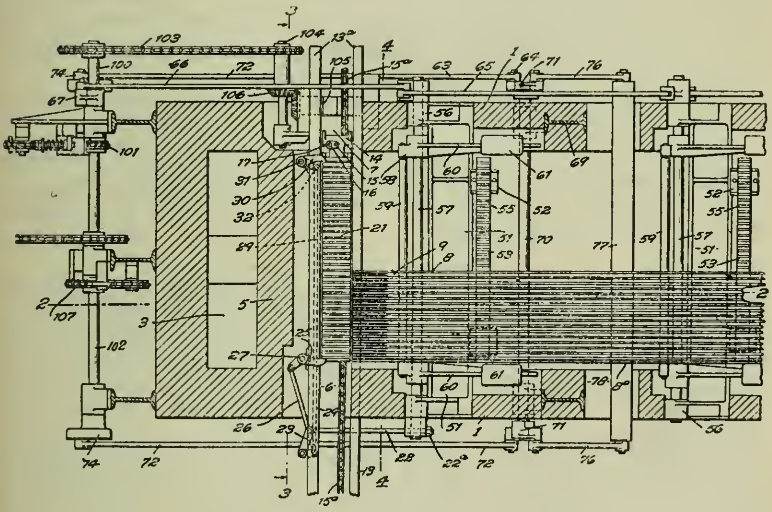

Fig. 97.

The front end of the lehr is shown in sectional plan in Fig. 97. The walls, crown, burner arrangement, etc., may be of any desired form; but the floor is made up of fixed bars, 8, alternating with movable bars, 9, the bars being arranged close to one another. Mechanism for moving the bars, 9, is described in the specification. The ware is taken into the lehr by moving carriages, 21, which are propelled along an endless track, 13, by driving chains, 15^a. The carriages support the ware on upstanding ribs, 21, the spacing of which corresponds with the opening of the bars, 8. When a train of cars arrives in the lehr, as shown, it is automatically disconnected from the driving chain, 15^a, and is automatically centred by levers, 25, 30. The movable bars, 9, move in between

the ribs, 21, on the carriage and lift the ware on to the bars, 8. The carriages then travel onwards and the operations are repeated.
G. D.

158. The Operation of Lehrs. C. E. Frazier (*J. Amer. Cer. Soc.*, 1922, **5**, 37).—Experience had shown that the initial temperature of the annealing chamber should be from about 425° to 595° and that the time necessary for maintaining articles at that particular temperature varied from forty-five to eighty minutes, depending on the shape and weight of the article and on the method of manufacture.

To anneal properly any piece of glass the following conditions were necessary: correct mould design, proper working temperatures, proper time and temperature in the annealing chamber, and correct rate of cooling of the ware after it left the hot end of the lehr.

Muffle and open type lehrs were compared. The former type, it was held, (1) gave more uniform temperatures in the annealing chamber, (2) prevented ingress of cold air beside the pans and thus avoided consequent cracking of the ware, (3) gave better control of temperature and greater trustworthiness of pyrometric indications, and (4) used less fuel per gross of ware.

Lehrs 8 feet in width and 65 feet in length were recommended for the average glass article.

In discussion, L. H. Adams pointed out that the exact annealing schedule required for any glass could be computed from the annealing constants of the glass which were known or could be determined in the laboratory.
F. W. H.

159. A New Form of Self-acting Regulator for Electric Furnaces. E. Haagn (*Elektrotech. Zeitsch.*, 1919, **40**, 170).—The regulator depended on the change in the resistance of the furnace winding with temperature and was therefore the more efficient the greater the temperature coefficient of resistance of the winding used. The coefficient when platinum was used was 0·4 per cent. per degree. The working cycle was as follows. Using an auxiliary resistance, *R*, to prevent overloading the furnace winding, the temperature was raised near to the desired point and then more resistance thrown in. The temperature slowly rose until at the desired point when, by means of the variable resistance, *S*, the iron pendulum, *K*, was midway between the coils 1 and 2. The current passing through 1, the interrupting apparatus, *M*, and the furnace in series was maintained and so the furnace got somewhat hotter than the desired value. The resistance increased and less current passed through the coil 1 and more through coil 2 which, with *S*, was in parallel with the furnace. The pendulum was attracted to 2, made contact at *K*, and a current flowed through the lamp, *L*, which was filled with inert gas and opened into the interrupter chamber, *M*. The gas expanded with the heat and drove the mercury down through the valve, *Z*, which it opened and up into *T* until the current through the interrupter was broken. The weight of mercury in *T* now closed the valve, Z, which had a pinhole in it, allowing the mercury to return slowly to M until the circuit was once again completed. The furnace cooled during this time and the size of the pinhole in Z could be arranged so that by the time the current flowed again the furnace was just below the desired temperature. Thus, for a 1—2 kilowatt furnace the mercury should take about ten seconds to re-establish contact after break. The heating and cooling cycles went on automatically, and it was claimed that a furnace as above could easily be maintained at a given temperature to ± 1°.

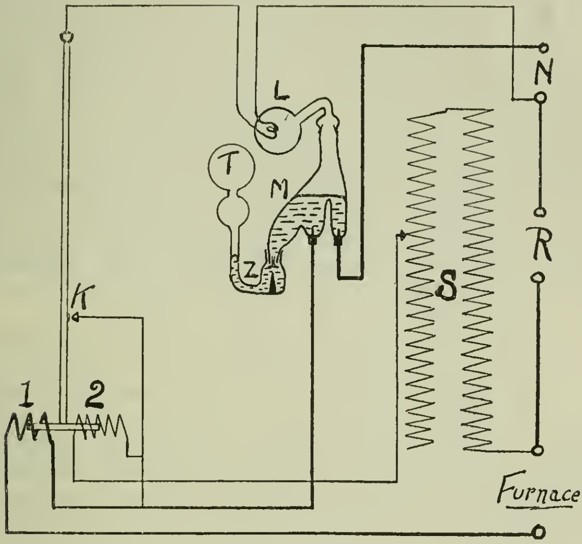

FIG. 98.

M. P.

160. A Thermocouple Connection. L. E. DODD (*National Glass Budget*, 1921, July 9th, p. 7).—The ordinary connecting piece or binding screw consisting of a hollow brass cylinder with a set screw to take each wire was condemned in that (1) it allowed a good deal of play between the round wall and the set screw, (2) the set screw bruised the wires, a serious objection in the case of the platinum metals. These defects were overcome at the Bureau of Standards by cutting a slot at each end of the brass rod, giving each face of the slot a slight radius, and passing a set screw freely through a hole in one side of the slot to engage in a threaded hole in the other and draw the two sides together, thus gripping the wire between. The natural "spring" of the metal prevented the screw slackening in use. M. P.

VIII. Chemical Analysis.

161. Determination of Available Lime in Quicklime and Hydrated Lime. Alice I. Whitson (*J. Chem. Met. Eng.*, 1921, **25**, 740).—In order to establish a ready, and yet trustworthy method for the determination of free calcium oxide in quicklimes and hydrated limes, a series of comparative analyses was made, by independent workers, on duplicate samples of high-calcium, and high-magnesium quick, and hydrated limes. Each of the seven methods given by R. K. Meade (*Concrete*, 1917, **10**, Cement Mill Section, p. 25) was tested, and the results were compared with those obtained in full gravimetric analyses. The Scaife method gave the most promising results, and in a more suitable and modified form very satisfactory results were obtained, independently, agreeing very well with the gravimetric values. The procedure of this modified method was as follows :

1·4 Gm. of the finely-ground sample were heated carefully in 200 c.c. of water, then boiled for three minutes in a beaker. After cooling, the beaker was washed down, then two drops of phenolphthalein were added, and the solution titrated with normal hydrochloric acid. The acid was added drop by drop, quickly at first with vigorous stirring to prevent any local excess. When the pink colour disappeared, and did not reappear for one or two seconds the reading was taken.

The experiment was repeated, using a 1 litre flask with a one-holed stopper fitted with a short glass tube drawn out to a point. Five c.c. less acid than required before were added on cooling. Suppose this number of c.c. be A. Any small lumps of lime were broken up, the solution was diluted, and made up to the mark with freshly-boiled distilled water, the flask was completely closed, and after thorough mixing the contents were allowed to settle for half an hour. A 200 c.c. portion was pipetted, and titrated slowly with $0{\cdot}5N$-acid, until the solution remained colourless on standing for one minute, the indicator being phenolphthalein. If this additional number of c.c. were B, then the percentage amount of CaO present in the sample was given by $\text{CaO} = 2A + 5B$. V. D.

162. Recent Applications of the Spectroscope and the Spectrophotometer to Science and Industry. S. J. Lewis (*Royal Society of Arts*, Cantor Lectures, April 1921).—In the first lecture a description of the quartz spectrograph was given, and the method of obtaining emission spectrophotographs was discussed. As a means of detecting and identifying traces of elements, this method was very sensitive, under favourable conditions showing the presence of quantities as small as one hundred-thousandth part of a milligram or one six-millionth part of a gram. In order to determine the constituents of two glasses, spectrophotographs were obtained by placing small quantities of the powdered glass on one pole of a copper arc. On examining the plates and picking out the characteristic lines, it was found that one of the glasses contained a notable amount of zinc and traces of lead and arsenic. Since these were not present in the second glass, it was assumed that the lead and arsenic were introduced into the glass as impurities in the zinc. The relative intensities of other lines showed that one glass contained more calcium and silicon than the other but less magnesium and boron. Attempts were being made to render this method more accurate for quantitative determinations.

In the third lecture dealing with absorption spectra, details were given of the absorption and transmission of three glasses and of quartz. A very deep red glass containing nickel showed no transmission in the visible spectrum, but transmitted some of the ultra-violet; Crookes "A" glass transmitted the visible spectrum practically unaltered, but absorbed all the ultra-violet; a spectacle crown glass transmitted the visible spectrum and a considerable portion of the ultra-violet; quartz transmitted freely waves of all lengths. Photographs of these absorption spectra were given.

S. E.

IX.—Machinery for the Working of Glass.

163. An Automatic Bottle-blowing Machine. C. F. Cox (U.S.A. Pat., No. **1385428**, July 26th, 1921. Filed June 4th, 1912, No. 701506).—The invention consists of a bottle-blowing machine all the operations of which are performed automatically after it has been fed with metal. The machine, which is shown both in elevation and in sectional plan, comprises a main stationary frame, 1, provided with a hollow central pillar, 2. A table, 3, mounted so as to revolve about the pillar, 2, carries four sets of bottle moulds, each set comprising a two-part ring mould, 4, a blank mould, 5, and a blow mould, 6. The ring mould and the blank mould are both fixed to a plate, 7, at the end of a hollow drum, 8, whilst the blow mould is carried on a support fixed to the table at a point radially outside the other two moulds. The drum, 8, has a gear, 9, which meshes with a gear, 10, fixed to the stationary frame, 1, so that, as the table, 3, is rotated about the pillar, 2, the ring and blank moulds are rotated about a horizontal axis. An overhanging arm, 32, clasped to the top of the hollow pillar, 2, carries a cylinder provided with a downwardly movable plunger the lower end of which has a head, 34, for finishing the bottom of the blank. A cylinder fixed below the table is provided with an upwardly movable plunger, 48, for forming the neck of the bottle. The two plungers, and a funnel, 119, for receiving the charge of metal are in alignment with one another, and shears, 93, for cutting off the excess of metal are arranged below the funnel.

The table with the attached sets of moulds is rotated by steps of 90°, means being provided for locking the table against further rotation after each step, so that the moulds, plungers, and funnel always come to rest in a given vertical plane.

The table is rotated, the moulds are opened and closed and rotated, the plungers operated, and all the other operations are effected by the use of compressed air, suitable pipes and valves being provided, the pipes being carried through the hollow central pillar.

In operation, with the moulds in position shown in Fig. 100, a charge of metal is inserted in the funnel, 119, and passing into the blank mould, fills both it and the ring mould. Suction may now be applied to pack the metal down into the moulds. The operator then depresses a trip lever, 111, with his punty rod to start the machine. The shears then close and reopen, and the upper plunger descends on the metal and presses it into the mould. The plunger is rotated at the same time to give a finish to the bottom. Simultaneously, the lower plunger, 48, rises, carrying the neck-forming head which enters the ring mould and is rotated at the same time to form and finish the interior of the neck. The plungers are then withdrawn and the table unlocked and rotated one step. As the table rotates, the ring and blank moulds are inverted by the rotation of the drum, 8, so that they come to rest with the bottle blank upright. The blank mould is then opened

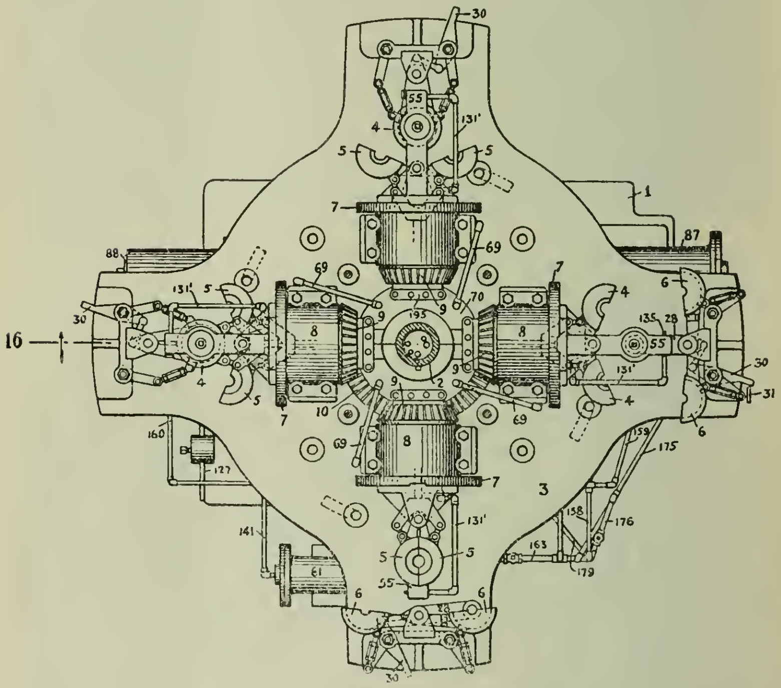

Fig. 99.

and the blow mould closed around the blank. As soon as the blow mould is closed, air is supplied through the mounting, 55, to the neck portion of the blank to blow the bottle.

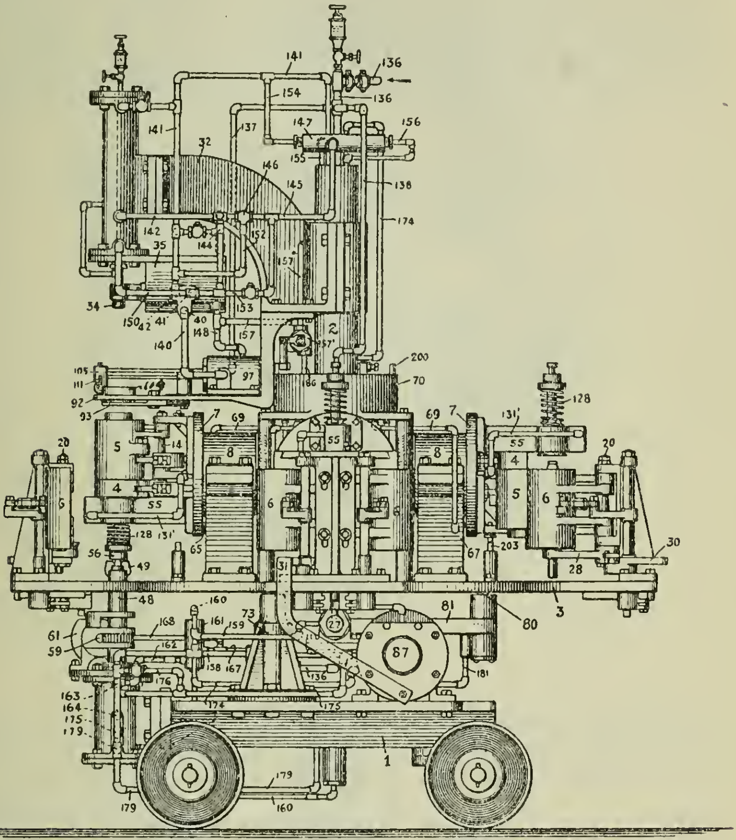

Fig. 100.

After the next rotation of the table, the moulds are brought to the position at the right-hand side of Fig. 99, and the ring mould is opened. At the next station, the blow mould is opened and the finished bottle is removed from the machine. G. D.

164. Improvements in Glass Bottle-blowing Machines. C. J. Dowdall, Dublin (Brit. Pat., No. **168167**, June 3rd, 1920).—Relates to glass-bottle and like blowing machines of the type in which the parison moulds are mounted on a continuously rotating frame and are filled by suction from a tank of molten glass. Fig. 101 is a diagram of the machine. According to the invention, the blowing-moulds, 9, are mounted on a uniformly rotating frame, 3, and the parison moulds, 51, are carried by swinging arms, 28, pivoted at 27 to the frame, 3. At station I, the finished ware is discharged. As the parison mould moves to station II it is swung forward, and at station III it is swung back so as to dwell in the furnace opening during gathering. At station V, the parison mould is opened and the suspended parison enclosed in the corresponding blowing mould. Each arm, 28, is splined on a spindle, 27, a pinion, 25, on which engages a toothed sector, 62, Fig. 102, having a spring arm, 64, which bears a roller, 65, engaging a cam-groove, 66, so shaped as to swing the arm, 28, in the required manner. The arm, 28, may be adjusted vertically on the spindle, 27, by a nut, 57, to accommodate parison moulds of different heights. The ring mould and parison mould are operated by cam-grooves, 39, 44, in a plate, 40, which is mounted on the spindle, 27, which does not, however, swing with the arm, 28. The plunger, 34, and knife, 35, are operated by cams formed on a frame, 48. The bottom of the spindle, 27, rests on a cam, 60, which lowers the

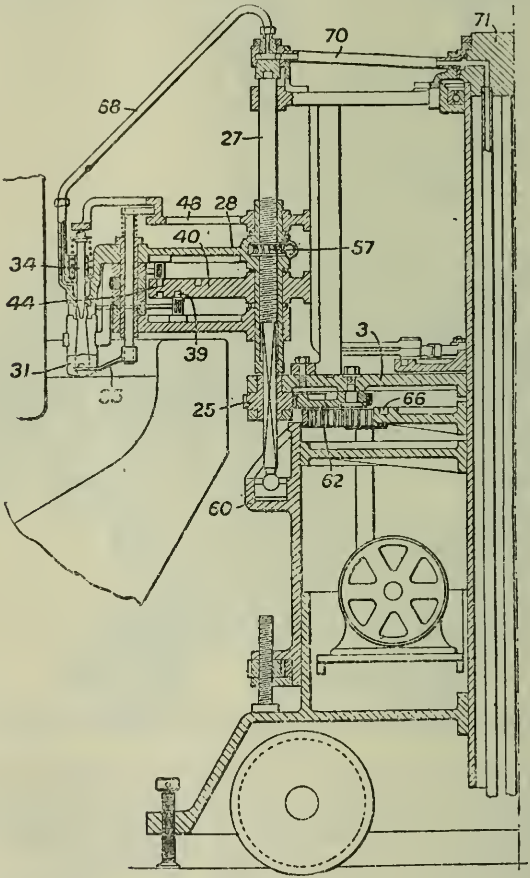

Fig. 101.

parison mould for gathering. A quadruple ring mould, 84, Fig. 102, is employed to avoid over-heating. Both halves, 84, are turned through 90° by ratchet mechanism each time the ring mould is opened so as to bring a fresh pair of mould cavities into operation. Vacuum for gathering and compressed air for blowing are conveyed through pipes, 68, 70, from a control valve arrangement, 71. H. G. C.

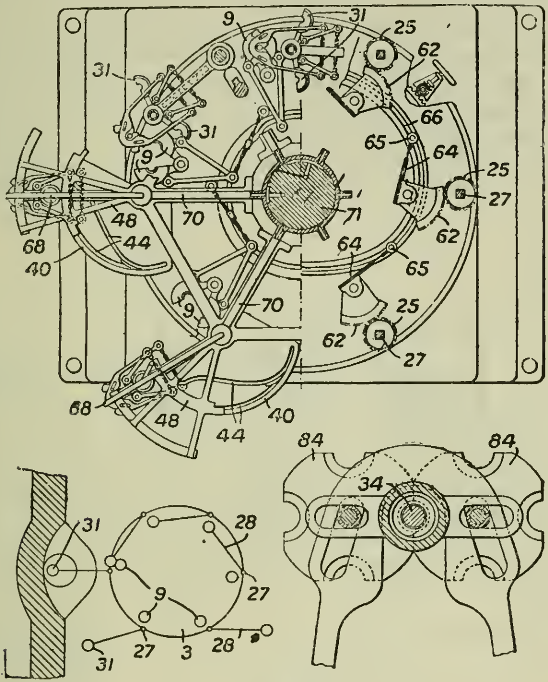

Fig. 102.

165. New Device in Making Glass Bottles. T. C. Moorshead, London (Brit. Pat., No. **168272**, November 15th, 1920).—Relates to the manufacture of glass articles such as bottles. Glass is delivered from the glass-tank by gravity into a divided mould, 4, which is formed with ports, 8, at the meeting edges, and suction is applied so as to draw the glass against the sides of the mould. The ports, 8, communicate with a suction-conduit, 9, in the mould slide, 10, which carries the table, 11, supporting the mould sections. A pouring-nozzle, 12, is placed over the mould.

H. G. C.

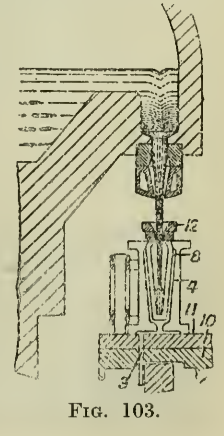

Fig. 103.

166. Press and Blow Machines. W. J. Miller, London (Brit. Pat., No. **171420**, May 10th, 1920).—Relates to press and blow machines of the type in which the moulds, etc., are carried by an intermittently rotating table. The blow moulds, *G*, are carried on a table, *C*, and below each is a parison mould, *F*, which is raised between the open halves of the blow mould, *G*, into contact with the corresponding ring mould, which is carried by an upper table, *H*. Each finishing-mould is provided with a bottom, 57, Fig. 104, mounted on a carrier, 51, which is moved radially in guides, 52, on the table, *C*, by fixed cams, 53. The finishing-moulds are recessed at 50 to admit the mould bottom, 57. The usual sequence of operations is carried out, namely, the parison mould is charged, the charge is pressed by a plunger, *K*, the parison mould, *F*, is lowered, leaving the blank suspended from the ring-mould, the blow mould, *G*, is closed, the ware is blown by a head, *J*, and the finished article is automatically removed by the sliding mould bottom and take-off grippers, 83, moving radially on rods, 84. The tables, *C*, *H*, are rigidly connected and are driven by the Geneva stop mechanism shown in broken lines in Fig. 104 The driving-

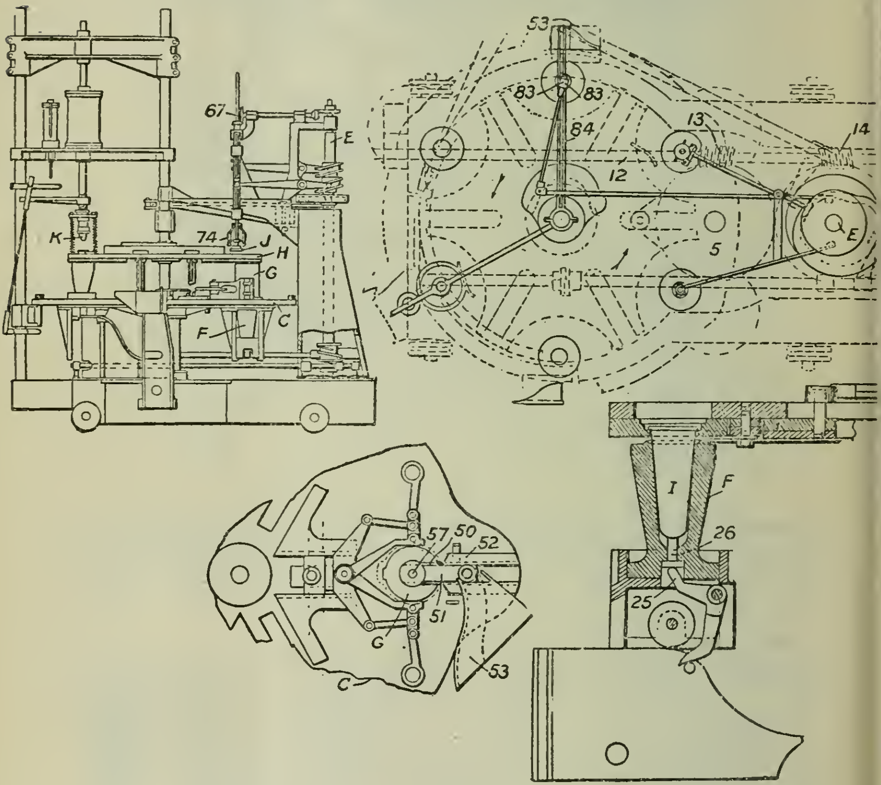

Fig. 104.

member, 5, of the Geneva mechanism and the vertical main cam shaft, *E*, are connected by spur gear, but are also independently driven by worms, 13, 14, on the main driving-shaft, 12. The parison, *I*, is fired from the mould, *F*, by a tappet, 26, which is raised by a bell-crank lever, 25. After the ware has been blown, the neck ring is lifted or unscrewed by spring tongs, 74, which, in the case of screw-necked bottles, are rotated by gear, 67. H. G. C.

167. Transfer Device for Press and Blow Machines. W. J. Miller, London (Brit. Pat., No. **168111**, April 26th, 1920).—

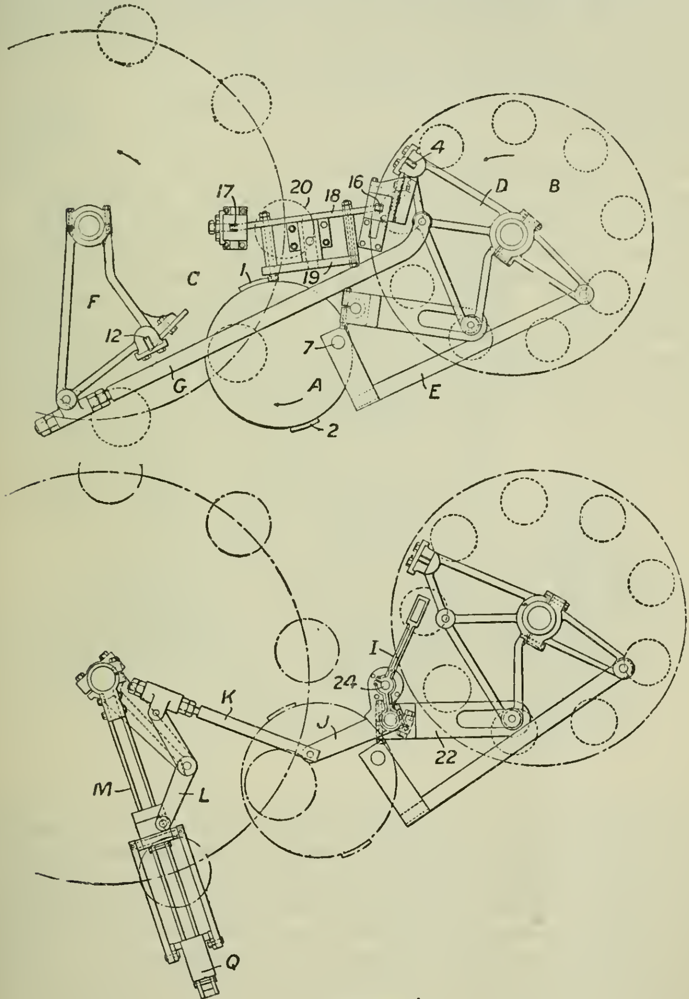

Fig. 105.

Relates to table-rotating-transfer, and delivery mechanism in press-and-blow machines of the double rotating table type. Fig. 105

is a plan of the mechanism below the parison-mould table, *B*, and blow-mould table, *C*. Oscillating arms, *F*, *D*, are connected by a rod, *G*, and are operated from a crank-pin, 7, by a rod, *E*. Locking-bolts, 12, 4, are provided, which engage the tables during the operative stroke and are disengaged during the return stroke. The parison-mould table, *B*, is moved through 40° and the blow mould table, *C*, through 80° at each stroke. Locking-bolts, 16, 17, are operated by rocking-levers, 18, 19, and cams, 1, 2, on the disc, *A*. A swinging transfer arm, *I*, is operated by a slotted lever device, 22, so as to start and stop slowly. It is raised and lowered by the piston-rod, 24, of a pneumatic device. Delivery grippers, *Q*, of any suitable kind are made to slide radially along rods, *M*, by the lever mechanism, *L*, *K*, *J*.

The tables, *B*, *C*, rotate in the same direction and are moved alternately. H. G. C.

168. Glass-making Machinery for Use with Feeding Devices. W. J. Miller, London (Brit. Pat., No. **169944**, April 1st, 1920).—Relates to machines for forming glassware of the type in which the moulds are carried on a rotary table, the aim being to adapt such a machine for use with a continuously flowing stream of molten glass. According to the invention, the table rotates continuously and the moulds are made to lag or the delivery apparatus is moved, so that there is no relative motion between these parts at the moment when the charge is dropped into the mould. In the form of apparatus shown in Fig. 106, the mould carriers, 24, are arranged to slide in curved slots, 27, and are formed with a projection, 30, which strikes a spring stop, 31, when the mould comes into the charging position. The mould is thus held below the feed-opening until the carrier, 24, reaches the end of the slot, 27, when the projection, 30, is forced past the stop, 31, and a spring, 28, pulls the carrier, 24, back to its original place on the uniformly rotating table, *C*. In the form shown in Fig. 107, the charge falls into a divided cup, *J*, mounted on a swinging arm, 37, which is engaged in turn by spring catches, 48, on the rotary mould table, *C*. The cup, *J*, is thus carried round above each mould, *E*, in turn and is opened by a fixed cam, 47, so as to drop its charge into the mould. On reaching a stop, 44, the

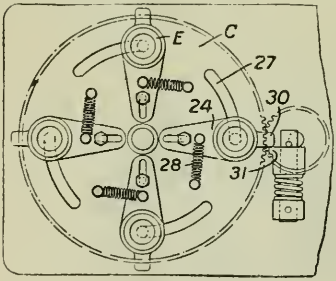

Fig. 106.

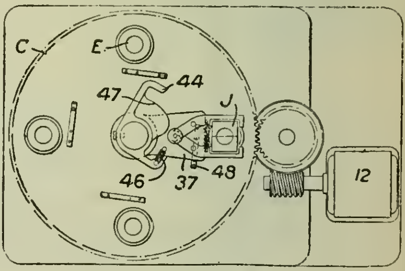

Fig. 107.

arm, 37, is disengaged from the catch, 48, and pulled back below the feed opening by a spring, 46. It is then charged ready to swing forward with the next mould. H. G. C.

169. Conveying Device for Transferring Glass Bottles to Lehrs. F. W. Danberg, Toledo, Ohio, U.S.A. (Brit. Pat., No. **168121**, May 17th, 1920).—An article-feeding apparatus more particularly intended for delivering glass bottles, jars, etc., to an annealing-bar or oven comprises a rotary support for the article which is moved at different speeds at different portions of the cycle of movement. In the construction described, two sector-shaped tables, 16, 19, each including an angle of about 120°, are mounted on a common axis. In operation a table is moved slowly past a delivery-shoot, 71, and articles are fed one by one on to a projecting shelf, 22. When the last article has been delivered the speed of rotation is doubled until the table is wholly within the mould of the bar, when its movement is momentarily arrested, and the shelf is withdrawn to deposit the articles on the moving band, 6. The motion is then continued at the higher speed back again to the feeding-point. The apparatus is mounted on a carriage, 1, on the platform of which is secured a stepped pedestal, 11, carrying independently rotatable sleeves, 12, 17, formed integrally with the tables, 16, 19. The rim, 20, of each table forms a guide for a segmental **U**-section slide, 21, carrying the projecting shelf, 22,

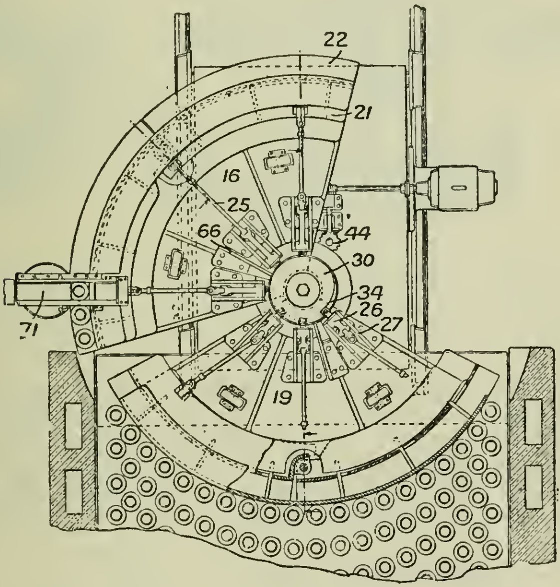

Fig. 108.

and secured to the rim in a segmental **L**-section abutment plate, 23. The slides are actuated by fixed cams, 30, levers, 26, pivoted at their upper ends to brackets, 27, links, 25, and springs, 33. A cam, 30, is provided for each of the three levers, 26, associated with a table, and a sharp step, 34, on each is so positioned that the levers will be actuated simultaneously by the springs, 33. The slide, 21, and shelf, 22, are divided at the middle, and the two parts are hinged together so that the movement at all points will be in a substantially radial direction, and to allow of this universal joints are incorporated in the limbs, 25, of the two outer operating-systems. The tables are driven by pinions, 42, 43, 44, Fig. 109, spaced 120° apart and engaging gear segments, 40, 41, fixed to the sleeves, 12, 17, by screws, 62, passing through holes, 63, which are slotted to allow a limited angular movement of the segment relatively to the sleeve under control of a spring, 64. When the table reaches the feed position in the bar a stop, 66, contacts with a spring-controlled trip arm on the bottom cam, 30, and the table is momentarily stopped. The gear segment moves relatively to the sleeve, and when the screws, 62, reach the ends of the slots the stop, 66, is forced past the trip arm. The pinion, 42, is driven at half the speed of the pinions, 43, 44. H. G. C.

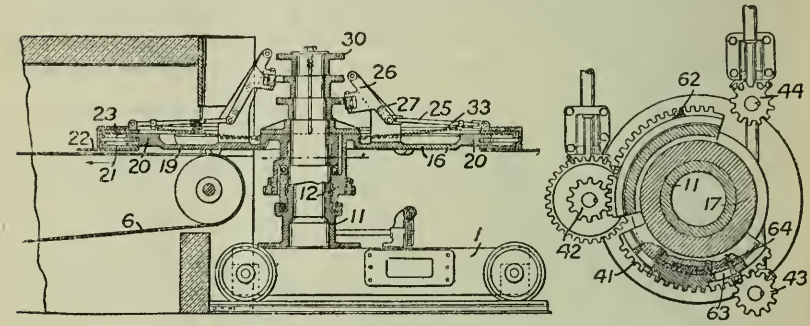

Fig. 109.

170. A Mammoth Glass Press. (*National Glass Budget*, 1922, **38**, June 3rd, 1).—Description of a press made by W. J. Miller, and designed for large pressed ware such as battery jars, punch bowls, or inverted shades. The machine was designed to work in conjunction with the large Miller automatic feeding device, stands 11 feet high, and takes floor space 7′ × 7′. The capacity ranges from 3—10 moulds of 16 inches diameter and 18 inches high. The plunger stroke is 14 inches and the maximum pressure developed by the toggle mechanism 150,000 lb., the plunger being actuated by an air cylinder and piston. The toggle mechanism has the advantage that the power of the stroke increases and the speed of the plunger decreases as it gets further into the metal and the mould fills up. M. P.

171. Apparatus for Drawing Glass Cylinders. J. J. Bloxsom and E. E. Myers (U.S.A. Pat. No. **1375818**, April 26th, 1921. Filed September 2nd, 1919, No. 321103).—The invention relates to cylinder-drawing apparatus of the kind in which the air for blowing the cylinder is supplied through a conduit, 10, running up through the pot, 2, and in which a number of pots are mounted on a rotating table, 1, which brings them to and from the drawing position. According to the invention, the air supply pipe, 9, has a telescope sleeve, 11, which is lifted to connect with the pot conduit, 10, by a lever, 13, that is actuated by a spring, 15, as a pot is brought into the drawing position. The lower end, 16, of the pipe, 9, is also closed by a valve, 17, controlled by a counterweighted lever, 19. As the table, 1, moves to replace an empty pot by a new one, an abutment, 21, on the table actuates the lever, 19, to open the valve, 17, thus allowing any broken glass which may have fallen into the air pipe to be discharged. G. D.

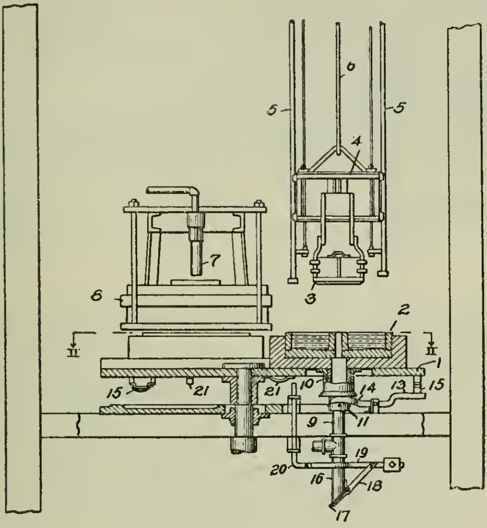

Fig. 110.

172. Drawing Sheet Glass by the Colburn-Libbey-Owens Process. I. W. Colburn and The Libbey-Owens Sheet Glass Co. (U.S.A. Pat., No. **1394809**, October 25th, 1921. Filed October 8th, 1915, No. 54714).—The invention consists of a method of making sheet glass by continuously drawing the sheet horizontally from a body of metal in a tank, arrangements being provided for regulating the temperature of the glass. The metal flows from the tank, 10, into a cooling tank, 11, and then into a drawing chamber, 12. In this chamber there is only a shallow pool of metal on the tile, 13, which forms the bottom of the chamber, and from the shallow pool the metal is drawn away continuously

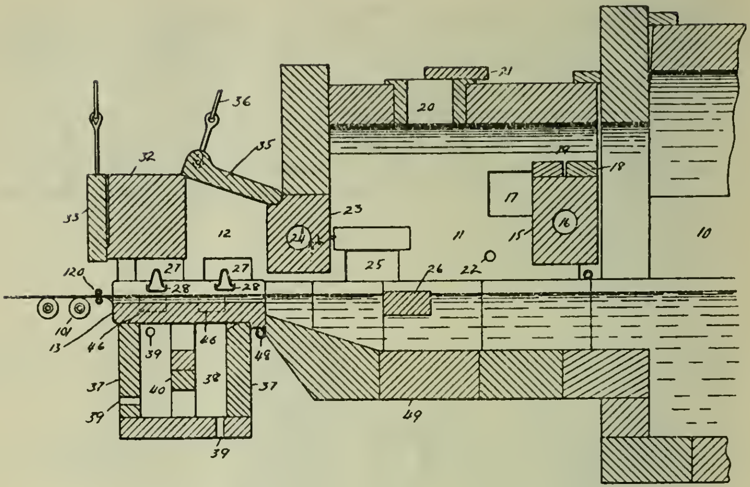

Fig. 111.

in a horizontal direction in the form of a flat sheet. The drawing power is supplied by endless belts which grip the sheet when it is cooled sufficiently to avoid being marked. The width of the machine is maintained by edge rolls, 120, as used in other Colburn machines, and the sheet is supported by rolls, 101. The temperature of the metal in the chamber, 12, is maintained at the correct point by water-cooled radiators, 28, and by a heating chamber, 38, beneath the tile, 13. Flues, 12, and 20, having openings to the air which can be regulated, assist in controlling the temperature of the body of the metal. G. D.

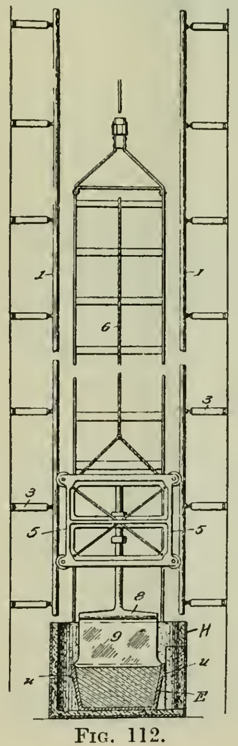

Fig. 112.

173. Drawing Sheet Glass. A. A. Icenhour and The Virginia Plate Glass Co. (U.S.A. Pat., No. **1407036**, February 21st, 1922. Filed April 17th, 1919, No. 290680). —In a process of drawing sheet glass, the sheet is drawn from a pot, *E*, that is oval in horizontal section and the greatest width of which is approximately the width of the sheet, 9, so that the edges of the sheet at the point of formation adhere to and travel down the walls of the pot, thus maintaining the width of the sheet. The oval shape of the pot also ensures that the hottest portion of the metal forms the centre of the sheet and that the edges are formed from cooler metal. Fig. 113 shows a sectional elevation, the furnace with the car, *G*, running on rails, which supports and operates the forked arm, *F*, for withdrawing the pots. In preparation for a draw, a pot is transferred to a small furnace, *I*, where it is allowed to cool to the drawing temperature and is then maintained at that temperature. Details of the carriage, *G*, are shown and described in the specification. G. D.

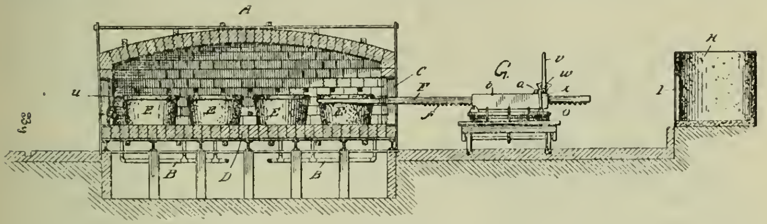

FIG. 113.

174. Drawing Glass Sheets. H. G. SLINGLUFF and PITTSBURGH PLATE GLASS CO. (U.S.A. Pat., No. **1364895**, January 11th, 1921. Filed March 28th, 1918, No. 225190).—The invention consists of a method of maintaining the position and thickness of the edges of the sheet during drawing, and consists in chilling the edges at their point of generation so that the glass tends to adhere to the chilling device, and at the same time provides a flow of hot metal through a cooled passage in the chilling device. The sheet, 15, is drawn upwards from a body of metal contained in a forehearth, the formation of the sheet being assisted by a drawing-bar, 12, beneath the surface of the metal as described in U.S.A. Pat., No. 1339229.* The ends of the sheet are drawn from the metal contained in pockets, 11, in blocks, 7, which also have pas-

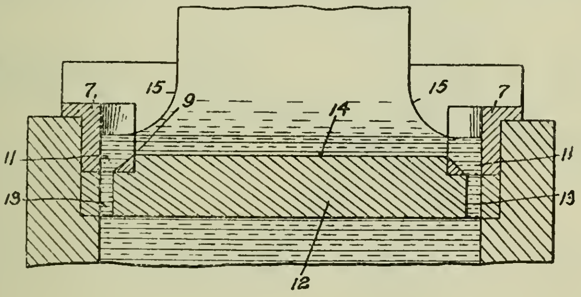

FIG. 114.

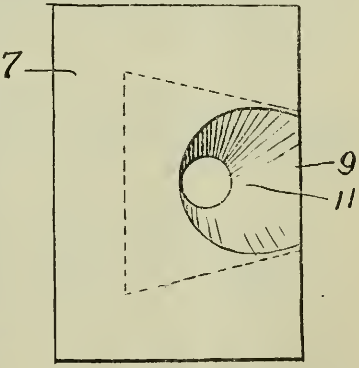

FIG. 115.

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* This Journal, ABS., 1921, 5, 46.

sages, 13, communicating with the body of the metal. The glass in the pockets is rendered viscous or adherent by the chilling action of the blocks, and the edges of the sheet maintain their position against the tendency to narrow or draw in. The supply of metal in the pockets is maintained by a flow through the passage, 13. Various constructions of the block, 7, are described in the specification. G. D.

175. New Method for Making Plate Glass. W. H. Powell (U.S.A. Pat., No. **1381591**, June 14th, 1921. Filed December 12th, 1919, No. 344365).—The invention consists in making plate glass by casting the plate, converting the cast plate, heating the rough surface thus exposed in order to melt it, and at the same time cooling the under surface.

The casting device consists of a ladle, 1, having a base portion, 2, and peripheral flanges, 3, and is filled by dipping it into a tank.

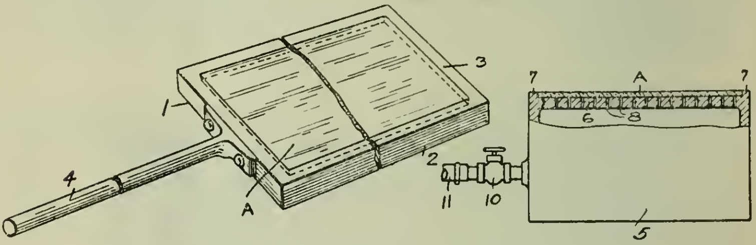

Fig. 116.

After withdrawal, it is allowed to stand until the contained glass, *A*, has set into a plate which will, of course, have a polished surface. When the glass has sufficiently set, the ladle is inverted to deposit the plate on the top of an iron box, 5, the top, 8, being perforated. The box is then placed in a furnace where heat is applied to the rough exposed surface of the plate, *A*, to glaze it. At the same time, air is blown into the box in order to keep the smooth under surface of the plate cool and to preserve its polish. G. D.

176. An Improved Casting-table for Plate Glass. W. J. Golightly and Pittsburgh Plate Glass Co. (U.S.A. Pat., No. **1366786**, June 25th, 1921. Filed April 8th, 1919, No. 288610).—

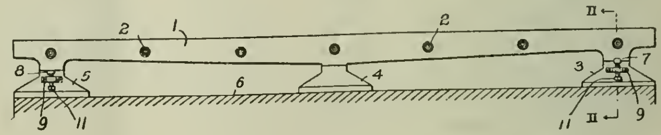

Fig. 117.

The invention relates to a casting-table, used in making plate glass, and consists of a construction designed to overcome the distortion of the surface due to expansion, which occurs as the table becomes hot. A table constructed according to the invention is shown in side elevation, and in cross-section. This table is made of longitudinal sections, 1, bolted together by transverse tie bolts, 2. It rests on foundation plates, 3, 4, 5, and at one end a transverse key prevents relative movement of the sections. At the other end, the table rests on a transverse bar, 8. The ends of the key, 7, and the bar, 8, are supported on adjusting screws, 9, which work through lugs, 9, in the foundation plates.

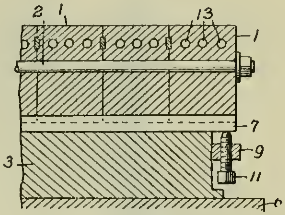

Fig. 118.

At first, the key, 7, and the bar, 8, rest wholly on the foundation plates, but as the table gets hotter, the screws, 9, are turned so that the weight of the table is more and more supported by the ends of the bars, 7 and 8. G. D.

177. The Moulding of Pavement Lights, etc. R. L. Frink London (Brit. Pat., No. **170721**, August 19th, 1920).—Relates to the moulding of solid glass articles such as vault lights, pavement prisms, port-hole lights, ink-wells, paper-weights, pedestals, door knobs, castors, electric insulators, etc. According to the invention, the apparatus consists of a moulding-chamber, 3, detachably secured to a vacuum chamber, 1, by clamps, 11, the chambers 1, 3, being separated by a perforated diaphragm, 2. The orifice, 13, is immersed in molten glass and the air is exhausted through a pipe, 6, and control valve, 7. When the mould, 3, is full, it is lifted and a shear, 15, operated. The finished article is removed when cool. H. G. C.

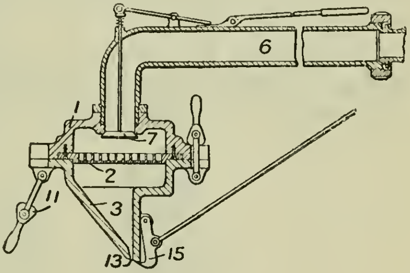

Fig. 119.

178. Device for Steadying Glassware in Glass-making Machines. J. W. Lynch and Lynch Glass Machinery Co. (U.S.A. Pat., No. **1406400**, February 14th, 1922. Filed March 5th, 1920, No. 363468).—The invention consists of a device for steadying the ware in the moulds of a bottle-blowing machine, in order to prevent the bottles from being displaced when the moulds open. As shown in elevation in Fig. 120, the device consists of a forked member, 18, adjustably secured to one end of a lever, 19, which is pivoted on a support, 24, attached to the central column, 14, of the machine. The lever is actuated by any suitable mechanism so that the member is brought down over the neck of the bottle just before the mould opens. The fingers of the member, 18, stand on each side of the neck of the bottle and prevent it from being drawn to one side by one of the mould parts. The distance between the fingers may be adjusted to suit necks of various sizes and the bracket may be adjusted up and down and angularly. G. D.

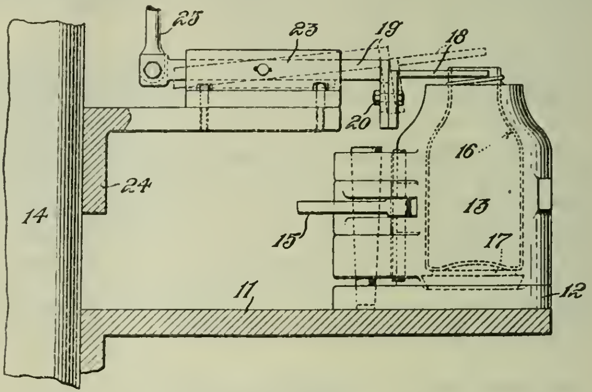

Fig. 120.

179. Method for Drawing Glass Tubing. L. N. Bruner Boulogne, France, and S. D. Olsen, Brooklyn, New York, U.S.A. (Brit. Pat., No. **170957**, August 4th, 1920).—Relates to the manufacture of tubes of glass or of other plastic material by drawing. The charge of glass, etc., is placed in a cylindrical mould, 26, which

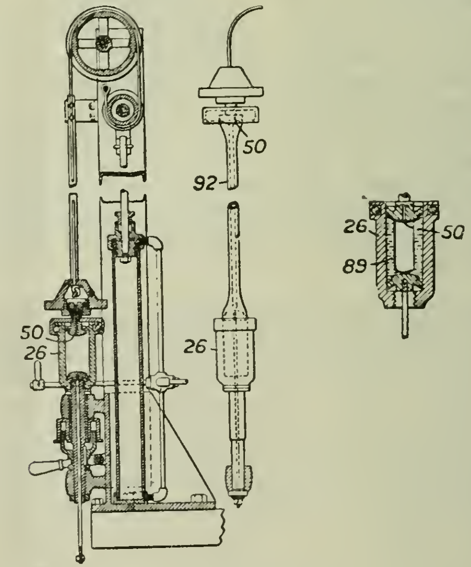

Fig. 121.

is then rotated rapidly, so as to cause the charge, 89, to rise by centrifugal force and engage an undercut lid, 50, which is then raised to draw out the tube, 92, to the required dimensions.

H. G. C.

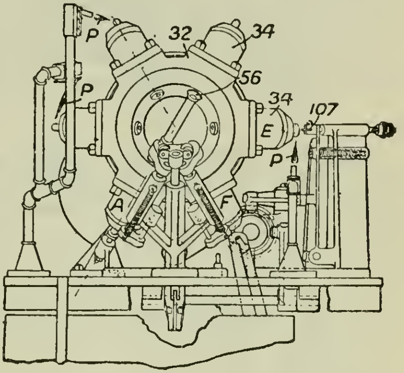

Fig. 122.

180. A Machine for Making Glass Flares. British Thomson-Houston Co., Ltd., London, and General Electric Co., Schenectady, New York, U.S.A. (Brit. Pat., No. **171232**, September 3rd, 1920).—Relates to a machine for flaring the ends of glass tubes and particularly those used in the manufacture of electric lamps. The apparatus according to the invention comprises an intermittently rotating head, 32, carrying six rotary chucks, 34. The glass tubes are fed singly through a fixed guide tube, 56, to the chuck occupying the position *A*. As the head, 32, rotates clockwise, the ends of the glass tubes are rotated by the chucks, 34, in contact with the flames, *P*, and, in the position, *E*, are acted on by a cam-operated flaring tool, 107. The tubes are discharged at position *F*.

H. G. C.

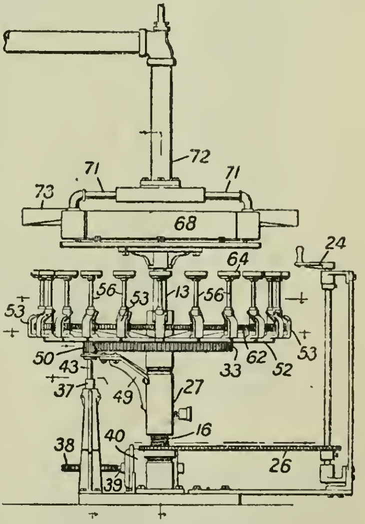

Fig. 123.

181. Fire-polishing Machinery. A. B. Knight, Fairmont, W. Va., U.S.A. (Brit. Pat., No. **171061**, January 26th, 1921).—Relates to rotary apparatus for fire-polishing the edges and sides of tumblers and other glassware. The ware is mounted in cups, 64, fixed on vertical spindles, 56, which are carried on a revolving frame, 52, and are rotated during revolution. The fire-polishing is effected by gas burners arranged in a semicircular casing, 68, with a projecting hood, 73, lined with fireclay or other refractory material. The burners are arranged to heat the fireclay and also the sides of the ware. The height of the frame, 52, is adjustable by means of a screwed sleeve, 27, which engages a screw, 16, on a sleeve free to turn on the central column, 13. The sleeve, 27, is held stationary by a bracket, 49, engaging a spindle, 43, free to move vertically in a fixed sleeve, 37, and is raised or lowered by rotating the screw, 16, by means of a handle, 24, and actuating-gear, 26. An electric motor, 40, actuates the spindle, 43, through gearing, 38, 39, and a pinion, 50, on the spindle actuates a spur wheel, 33, on which the frame, 52, is mounted. The rotation of the spindles, 56, is effected by pinions on them engaging a fixed central spur wheel, 62. The heating apparatus is carried on a plate fixed to the central column and is provided with conduits, 72, 71, for combustible fuel. The frame, 52, is provided with brackets, 53, to support the spindles, 56, and some of these brackets carry rollers which run on the upper surface of the gear-wheel, 62.

H. G. C.

182. A Sandblasting Machine. W. J. Miller, London (Brit. Pat., No. **168737**, July 9th, 1920).—A machine for treating glass or other articles by a sand-blast or like means comprises a number of rotating platforms, for supporting the articles, carried by a rotary table, each platform being located within a compartment and having associated therewith two movable jets; the jets become inoperative as each compartment in turn comes opposite an aperture in a casing surrounding the machine. On a bed, 1, is rotatably mounted, by ball bearings, 5, a table, 3, having near its periphery a number, preferably eight, of vertical sleeves, 7, in each of which is rotatably mounted a sleeve, 9, carrying a work-supporting disk, 14, of wood, etc., provided with grooves to allow the escape of sand from the interior of the article. The sleeves are rotated, during rotation of the table, 3, by the engagement of pinions, 15, thereon with a stationary circular rack, 16, the table being rotated by a pinion, 18, and teeth, 17, on the table. Secured to the table is a vertical hollow column, 21, supporting an upper table, 23, and between the tables, and associated with each platform, are sets of three hollow columns, 24—26. In each column, 24, is a slidable rod, 27, movable vertically by a cam, 29, and connected at its upper end to a lever, 31, adjustably pivoted to a standard, 32, on the upper table. Linked to the lever is a rod, 33, connected by a link at its lower end to a lever, 37, pivoted at 38 and carrying at its inner end a jet; rotation of the table thus causes oscillation of the jet whereby the sand is directed over the whole of the exterior of the article. The jet comprises a box, 39, having an outlet nozzle, 40, and a fluid-pressure-inlet nozzle, 41, sand being drawn in through a pipe, 42, from a reservoir formed by the table, 3, and walls, 43. The inner end of the lever, 31, is linked to a vertical rod, 47, slidable in the column, 25, and having at its lower end a bracket, 48, carrying a pipe, 49, slidable in the sleeve, 9, and carrying a nozzle, 51, for discharging sand on the interior of the article. Sand is drawn to this nozzle through a pipe, 54, and fluid is supplied by a pipe, 56. The main fluid supply pipe, 58, is located inside the column, 21, the upper end of which forms a fluid chamber, 59, having a port, 63, for each platform, each provided with a depending valve box, 64. Inside each box is a conical seat, 67, and a ball valve, 68, and each box is connected by a flexible pipe, 70, with the nozzle, 41; the pipes, 70, may be branched to supply both nozzles, 41, 51, for treating the exterior and interior of an article simultaneously. The top of the pipe, 50, carries an adjustable, and normally stationary, member, 71, which covers in succession the ports, 63, and so cuts off the sand-blast as the articles arrive at a position where they are to be removed. The valves, 68, are normally held raised by tappet rods, 72, resting on levers, 73,

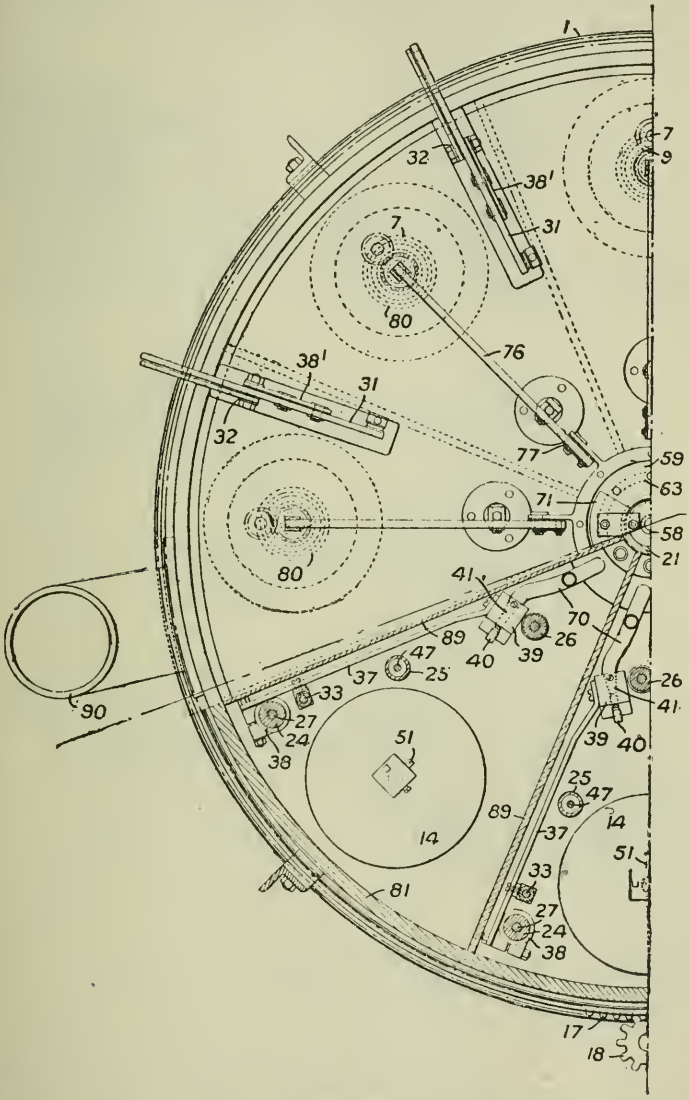

Fig. 124.

connected at their outer ends to levers, 76, pivoted at 77. These levers carry at their outer ends members, 80, which engage the tops of the articles under treatment. When an article is removed or broken, the member, 80, falls and the valve, 68, drops on to its seat, cutting off the fluid supply. A stationary annular casing, 81, encloses the space between the tables, 3, 23, extending into the sand reservoir and engaging at its upper end a flexible guard, 82, carried by the upper table. The casing has a take-out aperture, and as a platform arrives opposite this, the member, 80, is raised by a cam-operated rod, 84. Vertical radial partitions, 89, divide the space between the tables into segmental compartments each

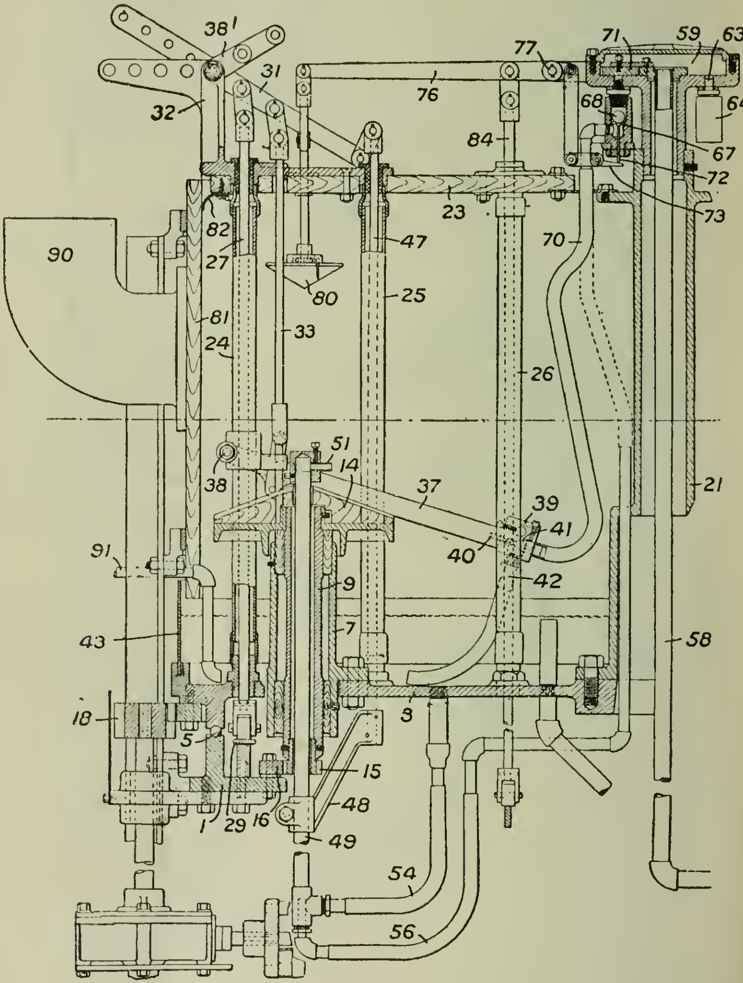

Fig. 125.

containing a platform and its associated jets, etc. The casing, 81, may have a vent hole, 90, for each compartment or communicating holes may be provided in the partitions and one vent hole only provided. A water inlet pipe, 91, may be provided for use when wet sand is required, and a sand inlet pipe may be provided for charging the reservoir. If the exterior only of the articles is to be treated, a short lever, 38′, may be substituted for the lever 31. In operation, the tables, etc., are rotated slowly or intermittingly, and stop, or slow down, when an article comes opposite the take-out aperture. Each article is carried round once by the tables, rotating meanwhile with its platform and being operated on by the jets as these are raised and lowered. H. G. C.

183. A Machine for Grinding Lenses. E. M. Long and Standard Optical Co., both in Geneva, New York, U.S.A. (Brit. Pat., No. **168379**, May 27th, 1920).—A machine for grinding the edges of elliptical lenses comprises means by which the lens is rotated in contact with a grindstone at such a varying angular velocity that all parts of its periphery shall be completed at practically the same time. A grindstone, 10, supplied with water from a reservoir, 5, is mounted on a shaft, 11, supported in a frame, 1, provided with an inclined guideway, 7, on which is bolted a movable section, 8. A sliding carriage, 16, is reciprocated on guides on the top of the section, 8, by means of a piston in a cylinder supplied with fluid from a pendent pump, as described in Specification 151303. A lens-holder frame, 62, pivotally mounted on arms, 60, on the carriage, 16, is urged towards the grindstone, 10, by weighted levers or springs. A shaft, 65, journalled in an extension, 64, of the frame, 62, is driven from a shaft, 43, through a flexible shaft, 68, and spiral gears, 69, 70. The upper end of the shaft, 68, is journalled in a yoke, 72, pivoted on an eccentric rock-

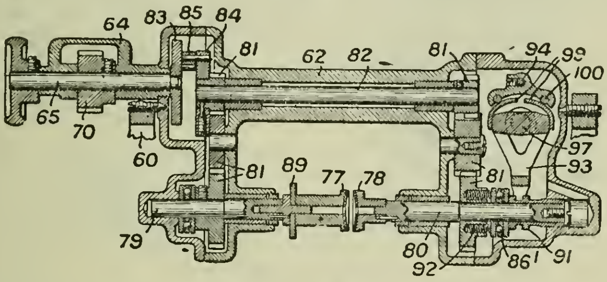

Fig. 126.

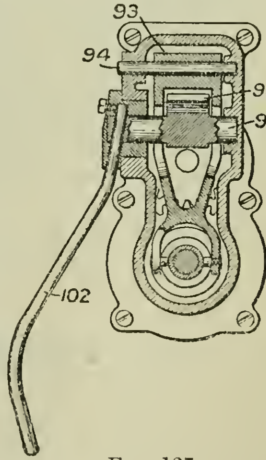

Fig. 127.

shaft, 73, carried by arms, 74, on the extension, 64. A handle, 75, serves to rotate the eccentric shaft, 73, and throw the gears, 69, 70, out of mesh. A disc (Fig. 128) on the shaft, 65, drives at a varying speed a disc 84, on a parallel shaft, 82; a link, 85, connects the discs 83, 84. Lens-clamping members, 77, 78, provided with pads, rotate with spindles, 79, 80, which are driven by 2 : 1 reduction gears from the shaft, 82. A hand-lever, 102, Fig. 127, partly rotates a rock-shaft, 97, having cam-surfaces, 99, which engage pins, 100, on a rock-arm, 93, pivoted on a spindle, 94.

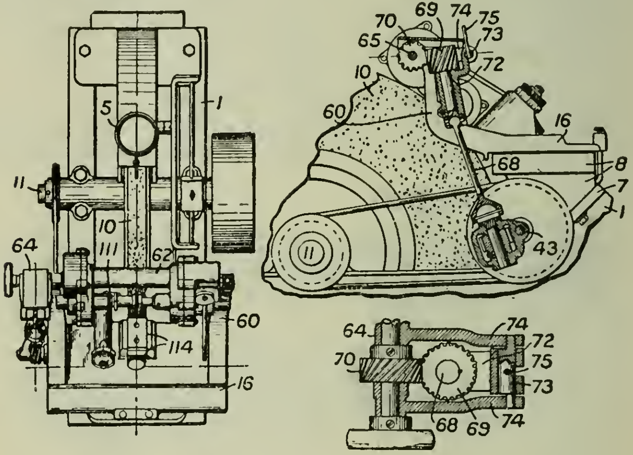

Fig. 128.

The pins, 100, act readily on the shaft, 97, and so lock the latter in any position. The end of the arm, 93, engages a grooved collar, 91, slidable on the shaft, 80, and transmits, through this collar, 91, thrust ball bearings, 86′, and springs, 92, a longitudinal movement to the shaft, 80, thus clamping a lens between the members, 77, 78. A lens-pattern, 89, on the member 77 bears against an adjustable back-rest, 111, Fig. 128, and causes the frame, 62, to swing towards and from the grindstone and thus grind a lens, between the members 77, 78, to the required shape. The grindstone is kept true by an adjustable device, 114. H. G. C.

X.—Glass Accessories.

XI.—General.

184. Glass Containers. A. W. Bitting (*J. Amer. Cer. Soc.*, 1922, **5**, 85).—At the present time more than 4000 different sizes and shapes of glass containers were being made and the industry was in a state of rapid extension.

Standard types of bottles should therefore be decided on. Tall bottles and jars with narrow bases were not as easy to handle by machinery as the more sturdy types. Certain shapes lent themselves to pasteurisation and processing better than others. The laws of physics relating to expansion and contraction could not be set aside just to have a panel bottle.

American-made glass containers could be classified into six groups, namely, (1) beverage bottles; (2) proprietary and prescription bottles; (3) food containers; (4) general purpose containers: wide mouth for dry drugs, chemicals, and heavy materials; narrow mouth for drugs and chemicals, oils, varnishes, polishes; (5) large containers: such as 1- to 12-gallon bottles and carboys for water bottles and chemicals; and (6) special containers: such as battery and display jars, etc.

The Glass Container Association had tested 180 lots of beverage bottles as a preliminary step towards determining their strength and suitability to meet certain requirements.*

The bottles were grouped according to diameter, capacity, weight, ratio of weight to capacity, and shape, for the purpose of comparison. Any bottle with a long, sloping shoulder of the champagne type, having a uniform distribution of metal and being well annealed, was a strong type.

The round type of prescription bottle was distinctly the strongest and then followed in order, the oval, the square, and the panel. The uneven distribution of glass due to square shoulders, sharp corners, flutes, and panels, and irregularities in shape which permitted excessive pressure on small areas in packing, helped to make the difference between the non-fragile and the ware which needed the label "Handle with Care."

The matter of the soluble alkalinity of glass had been receiving more attention recently than in the past. It was probable that less than 0·05 per cent. of the articles packed were affected by free soluble alkali. American bottles were stated to be better in this respect than foreign ones. F. W. H.

185. The Indispensable Glass Milk Bottle. (*Glass Container*, 1922, **1**, 8).—A compendium of current opinion for and against glass milk bottles.

An effort had been made in New York to introduce paper containers for milk, but completely failed.

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* See this Journal, Abs., 1922, **6**, 15.

The glass container was strongly advocated for the following reasons:—

(1) The cream line was distinctly visible, and dirt could easily be detected.

(2) The glass bottle shape enabled it to be produced economically by machinery.

(3) Bacterial growth was less in glass than in paraffin paper.

(4) The glass imparted no taste or flavour to the milk.

(5) Milk was easily iced and handled in glass.

(6) Glass was the most sterile of all containers.

(7) Leakage was prevented. V. D.

186. Machinery and the Glass Package. (*Glass Container*, 1922, **1**, 10).—An article dealing chiefly with bottle-washing. After its actual manufacture, a container had to withstand several processes, such as cleaning, sterilisation, filling, capping, labelling, and conveying. Hand methods were regarded as very defective.

V. D.

Reviews.

Journal of Scientific Instruments. Edited by E. H. Rayner, published by the Institute of Physics.—Scientific workers in this country have frequently felt the need of some work of reference in connection with the development of instruments and processes as apart from actual measurements themselves. There has been, for example, no journal in this country similar in character to the *Zeitschrift für Instrumentenkunde* and its supplement the *Deutsche Mechaniker-Zeitung*. Here, at any rate, one may find reference to apparatus and plant, especially those which are useful in research in physics.

The journal under notice is intended to meet the need. Indeed, from its preliminary number one may expect it to outdistance the somewhat similar German periodical by reason of its thoroughness. Unfortunately, the project is not yet fully and absolutely decided on. The decision depends on the result of a canvass which the preliminary number is intended to assist. We sincerely trust, however, that the decision to proceed with its publication will be made.

The preliminary number consists of a series of articles written by authorities in various branches of pure and applied physics. Sir J. J. Thomson and Dr. Rayner have something to say about the general scheme for the journal. Prof. A. V. Hill writes on "Instruments and Apparatus in Relation to Progress in Physiology"; Sir Frank Dyson on "The Use of a Reference Plate for the Micrometric Measurement of Astronomical Photographs"; Sir Chas. Close on "The New Fundamental Bench Mark of the

Ordnance Survey"; Messrs. F. Twyman and J. H. Dowell on "The Optical Sonometer"; the Research Staff of the General Electric Co., Ltd., on "Two Machines for Rapidly Weighing Loads of a Few Milligrammes"; Dr. J. Robinson on "The Reid Control Indicator for Aeroplanes"; Dr. J. S. Anderson on "The Measurement of the Internal Diameters of Transparent Tubes," and Mr. G. A. Tomlinson on "The Production of Uniform Cylinders of Small Diameter." In addition, there is an account of the Physical and Optical Societies' Exhibition, Reviews, Notes as to the future of the journal, and Abstracts of recent patents.

If the plans of the founders proceed as expected, the journal will be issued monthly at the subscription price of 30s. a year. We believe the time is ripe for such a journal. W. E. S. T.

Coal, Coke, and By-products. (1913–1919.) (London, IMPERIAL MINERAL RESOURCES BUREAU. Part I, 1921, 124 pp. Price 3s. 6d. net. Part II, 1922, 159 pp. + 13 maps. Price 6s. 6d. net.)—Part I is a digest of statistical and technical information relative to the production, consumption, and value of coal, coke, and by-products. It comprises (*a*) general information in respect of coal, coke, and by-products; (*b*) the world's production, and (*c*) coal statistics of the United Kingdom. The second part contains similar information in respect of the British Empire other than the United Kingdom. Maps of the coal-fields dealt with in both parts are included in Part II. F. W. H.

Iron Ore. (London, IMPERIAL MINERAL RESOURCES BUREAU. 1922. Part I, United Kingdom, 237 pp. + map. Price 6s. net. Part II, British Africa, 76 pp. + map. Price 3s. net. Part III, British America, 115 pp. + map. Price 3s. 6d. net. Part IV, British Asia, 65 pp. + map. Price 2s. 6d. net. Part V, Australia and New Zealand, 106 pp. + 6 maps. Price 4s. net). F. W. H.

Durability of Optical Glass. (London: THE BRITISH SCIENTIFIC INSTRUMENT RESEARCH ASSOCIATION, 26 Russell Square, W.C. 1. Price 7s. 6d.)—A lengthy abstract of this report appears elsewhere in this JOURNAL, and it now remains only to make a few general remarks. We must begin by welcoming such a valuable report, the first, so far as the reviewer is aware, which has been made available by the Association for the general scientific public.

The problems connected with durability are of two kinds, namely, the influence of chemical composition and the effect of the physical treatment of the surface such as polishing. It is clearly shown, by the use of the iodoeosin test, that (1) a polished surface is more durable than a fractured surface, (2) a freshly-fractured surface is more readily corroded than one which has been previously subjected to a moist atmosphere. This second fact is already well known and accords also with the known improvement of glass surfaces by washing with water. Two other interesting phenomena were observed. The first was that the surface fractured under iodoeosin is in many cases readily corroded even more than the fresh surface fractured in air. Momentary rise of temperature as the result of the fracture does not seem to be sufficient explanation, and the authors of the report are themselves unable to furnish a satisfactory general theory. The second matter of special interest was that photomicrographic observations revealed the presence in the glass specimens of spots of greater durability than the surroundings.

The chemical aspect of the problem was dealt with by making special meltings of approximately known composition. The general results in this section, however, do not disclose much that is entirely new. The work would have been made more complete by the inclusion of the chemical compositions of the commercial optical glasses tested, although these compositions were rather diverse. As the result of the comprehensive study made, the authors are not able to recommend any one method of testing durability. The report is bound to be of great interest to all glass technologists.

The reviewer may be permitted to suggest that the open publications of Research Associations might with advantage be made through the medium of organised scientific societies. There is undoubtedly much justifiable pride in the publication of such a valuable report as the one under review, and the individuality of the Association is emphasised by its manner of publication. On the other hand, the communication of such results to scientific societies has the undoubted advantage of stimulating discussion, of ensuring wide distribution, and certainly of economy.

W. E. S. T.

I.—Glass-making Materials.

187. Salt-cake in the Glass Industry. H. KÜHL (*Glashütte*, 1922, **52**, 225, 241).—According to the author, salt-cake was introduced into the glass industry by the Russian, Laamann, who, in 1764, tried a substance obtained from Chudsir, a natural Siberian sodium sulphate, by heating this with charcoal. The product was a mixture of the sulphide, carbonate, and sulphate. The use of salt-cake was first recommended in Germany by Lampidius towards the close of the eighteenth century, but without success until, in 1803, Von Baader first made trials with the material in the factories of the Bavarian woodland districts. In 1808, Gehlen also attempted to use salt-cake, but without satisfactory results. Then, as now, the great problem was the reduction of the substance, and in 1846 Girardin published his observations on the subject in the *Journal de Pharmacie* following a series of analyses of glass gall. He found the great bulk of the gall, as obtained from bottle, hollow-ware, and window glass furnaces, consisted of undecomposed salt-cake (56 to 90 per cent.) with appreciable quantities of calcium sulphate (6 to 25 per cent.) and smaller amounts of salt, lime, alumina, etc. The following essentials were put forward by the author for the successful use of salt-cake: (1) a sufficiently hot furnace, (2) materials as dry and finely powdered as possible, with only the coal granular, the latter being first intimately mixed with the salt-cake, then the lime and finally the sand being added, (3) decolorising to be done after complete melting of the batch, (4) gall first removed after complete melting. A. C.

188. Natural and Artificial Cryolite in the Glass Industry. L. SPRINGER (*Glashütte*, 1921, **51**, 324, 339).—Natural cryolite came from Greenland, where a private company had obtained mining rights from the Danish Government. As mined, the mineral contained quartz and sulphate earths, the method of purification being confined to hand sorting. A typical analysis of pure Greenland cryolite was: sodium aluminium fluoride 97·67, calcium oxide 0·02, iron oxide 0·20, silica 1·74, moisture 0·27 per cent. (approx. 60 per cent. NaF, and 40 per cent. AlF_3). The substance was a colourless, fairly soft material, with a glassy appearance and a fatty feel. In the glass industry it acted as a flux, owing to its low melting point (925°); it was only slightly decomposed and passed into solution in the glass. On cooling, it was precipitated, so acting as an opaliser. Chiolith, found in the Urals, was a somewhat similar substance, of a composition approximately 40 per cent. NaF, 60 per cent. AlF_3. Artificial cryolite of exactly the same composition as the natural product could be obtained, but had the disadvantage of being less stable when heated, so proving a less powerful opalising agent. On the other hand, it could be obtained with a smaller iron oxide content.

Synthetic chiolith, with a higher aluminium fluoride content, was better than artificial cryolite. Artificial cryolites usually contained silica, soda, and sodium silicofluoride, besides sodium aluminium fluoride, and consequently had a smaller opalising power. The following were the percentage compositions of three synthetic cryolites : (1) sodium fluoride, 55·9; aluminium fluoride, 39·8; soda, 3·3; water, 1·38; iron oxide, 0·01; (2) sodium fluoride, 50; aluminium fluoride, 18; silica, 32; (3) sodium silico-fluoride, 40; aluminium hydroxide, 36; soda, 24 per cent. A fairly large silica content, although not in itself harmful, resulted in a less efficient substitute, and mixtures containing such should not be named "synthetic cryolites." Successful results were more likely to follow from the use of natural cryolite, which, according to C. F. Jarl, contained no traces of lead, zinc, or copper, and not more than 0·2 to 0·3 per cent. of quartz. The mineral, further, was regular in composition, whilst artificial cryolites were more or less variable. As against a melting point of 925° of the natural mineral, substitutes melted at about 600° and decomposed more readily. An Austrian glassworks gave the life of pots in which the best synthetic cryolite was used as four weeks, of those in which natural cryolite was used as seven to eight weeks, whilst 10—15 per cent. less of the latter than of the former material was required. Loeser had stated that sodium silicofluoride was better as an opaliser than fluorspar (since the latter reacts with silica), and also than cryolite. The author, using equivalent quantities of the three substances, obtained good opal glasses with the fluorspar and cryolite, but only a faint opalescence with the silicofluoride. This last material directly decomposed with evolution of silicon fluoride. A. C.

189. How to Distinguish between Natural and Artificial Cryolite. L. Springer (*Glashütte*, 1921, **51**, 276).—When a fairly coarsely powdered sample, in a medium such as glycerin, was examined microscopically against a dark background, the grains of the natural product were bright and transparent, those of the artificial material matt-white. Natural cryolite had no effect on litmus paper, but cryolite substitutes were not always neutral in behaviour. Finely powdered mineral cryolite mixed with cold water at once formed a gelatinous, transparent mass at the bottom of the vessel; the artificial product remained for a long time as a milky suspension. On boiling a sample with water for several minutes and filtering, the following distinguishing tests were applied to the filtrate : (*a*) When evaporated to dryness, a residue containing more than 3 per cent. of the sample, or consisting of distinct amounts of fluorides, chlorides, sulphates, or carbonates, indicated the artificially prepared material; (*b*) the solution from natural cryolite gave, with baryta water or barium chloride solution, no precipitate, but in the case of artificial cryolite a white precipitate was formed; (*c*) in both cases lead acetate solution gave a precipitate, soluble in excess, however, only in the case of the natural product. To a hydrochloric acid extract of the material ammonia was added and the natural cryolite gave little or no precipitate of alumina; the artificial substance gave a larger precipitate. About ½ gm. of powdered material was shaken with 10 c.c. of bromoform (sp. gr. 2·83); the artificial cryolite floated, but natural cryolite settled within half an hour. On boiling 5 gm. of natural cryolite in 220 c.c. of a 20 per cent. aluminium chloride solution, the material slowly dissolved, giving, after two to three hours, a small residue of quartz. Artificial cryolite either dissolved at once completely or, after a long period, left a noticeable residue.

A. C.

190. Phonolith in the Glass Industry. H. KÜHL (*Sprechsaal*, 1922, **55**, 313).—Phonolith, a natural rock, contained large amounts of alkali and alumina and about 2 per cent. of iron oxide. Zsigmondy had showed it to be usefully incorporated in glass designed to absorb strongly heat radiation, the absorption being due to ferrous oxide. Decolorisation of the glass was only possible when phonolith was added in very small amounts, and when it was present to the extent of 20—25 per cent. a wine-bottle green colour was obtained. The following batch : sand, 604; soda-ash, 200; limestone, 80; barium nitrate, 60; boric acid, 20; phonolith, 350 kg. gave a glass containing about 7 per cent. of alumina. In a crucible it melted easily and rapidly, but the glass formed had too high a coefficient of thermal expansion to be used for illuminating ware. The colour of the above glass was green, and this was modified to various beautiful tints by the following colouring agents : blue-green, 10 gm. copper oxide, 1 gm. nickel oxide; green, 10 gm. copper oxide, 8 gm. potassium chromate; light blue, 10 gm. copper oxide, 1·5 gm. cobalt oxide; deep blue, 10 gm. copper oxide, 3—4 gm. cobalt oxide. A deep green glass, easily melted and worked, was obtained from the following batch : sand, 600; soda-ash, 200; limestone, 80; barium nitrate, 25; boric acid, 30; phonolith, 350; uranium oxide, 6; pyrolusite, 25 kg. A glass made from sand, 80; salt-cake, 40; limestone, 25; witherite, 2; phonolith, 100; coal, 8; sulphur, 2; iron filings (or sieved iron turnings), 4 kg. was completely black if viewed in sheets of 4—5 mm. thickness. It was suggested by the author that a glass containing phonolith would be suitable for the production of a copper-ruby colour.

A. C.

II.—Glass : Manufacture and Properties.

191. Manufacture and Properties of Optical Glass. F. WEIDERT (*Monatsblätter des Berliner Bezirksvereines deutsche Ingenieure*, May 1921. See also *Sprechsaal*, 1921, **54**, 423, and *Glashütte*, 1921, **51**, 789, 803, 820; 1922, **52**, 1, 17.—The war brought prominently to the notice of Germany, and more particularly to her enemies, how few optical glass factories existed in the world. Until shortly before the war there were only three of importance, Messrs. Chance Bros. in England, the firm of Parra-Mantois in Paris, and Schott and Gen in Jena. The dependence of the German optical glass industry on a single glassworks and the necessity of an alternative source of supply resulted before the war in the resuscitation of the Sendlinger Optical Glass Works. This works was originally founded by C. A. Steinheil, who was instigated to make optical glass by Joseph v. Fraunhofer. His descendant, Dr. Rudolf Steinheil, took up the idea of making optical glass, and through laboratory experiments followed up by small experimental melts in a glasshouse acquired sufficient information to warrant him building a modern glasshouse near Munich for the production of optical glass. This works, regarded simply as a research institution for important work, was closed down after two years, but opened again in 1913 when the absolute necessity of a further source of optical glass in Germany became evident. A contract with the Goerz Co. and a guarantee that they would supply all the scientific assistance in their power assured the success of the new undertaking, which grew during the war until in 1916 it was found necessary to transfer the work to a new and extended factory near Berlin.

The author gave a general account of the methods which they employed in the manufacture of optical glasses, the batches, the type of furnace and pots used, and the phenomena observed during the melting process. It was particularly noted that certain types of optical glasses—and of these the most valuable such as heavy barium crown and boro-silicate crown glasses—could not be obtained entirely free from seed.

After the glass became plain it was skimmed to remove surface impurities, stirred to render it homogeneous, and then cooled, the cooling process lasting about fourteen days. The pieces of glass selected from the pot were melted down into slabs in small, square fireclay boxes, and these slabs subjected to "fine annealing" over a period of four to six weeks. A melt yielding 20 per cent. of first-class glass was regarded as successful.

In the case of any particular glass, two characteristic temperatures were of special importance, namely (1) the temperature at which the molecules of the glass could just move (and the glass just ceased to be a solid body), and (2) that at which the glass practically lost its individual shape and its surface tension and internal stresses were overcome by gravity. These temperatures could be considered as the lower and upper limits of the annealing range, respectively.

The upper limit—the "flowing temperature"—was determined by heating a cube of glass bedded in kieselguhr to a definite temperature for half an hour in an electric furnace and then cooling suddenly. The flowing temperature was that at which the highest cube angle was melted smooth. It was found to be lowest with flint glasses and highest with barium crowns.

The lower limit, the temperature at which the glass received the first traces of mechanical stress, was also found to be lowest in the case of flint glasses and highest with barium crowns.

The initial temperature necessary for the efficient cooling of the glass was its "annealing temperature." Cubes of glass in which the strain had previously been determined were heated to a definite temperature (300—350°) and cooled gradually in an electric furnace. After four weeks' cooling, the residual strain was measured and the relation between the initial temperature and residual strain established. Curves plotted on these lines showed that some glasses lost their strain very late, but then suddenly, while others (for example, flint glasses) began to lose their strain early but continued very gradually.

When the exact annealing temperature was unknown it was unsafe to rely on using a high temperature, since this gave rise in some cases to devitrification. The devitrification and annealing temperatures of some glasses lay so close together that whilst they could be made successfully on a laboratory scale they could not be repeated on a manufacturing scale on account of the slower cooling and consequent devitrification.

Table I gives data on the flowing temperature and other properties of the glasses tested.

TABLE I

Type.	Temp. of Flow (½ hour)	Deformation Temp. (6 hours)	Annealing Temp.	Devitrification Temp. Lower.	Devitrification Temp. Upper.
Flint 649/338	660°	430°	380°	720°	825°
Flint 613/369	730°	460°	405°	720°	875°
Crown 519/604	770°	520°	420°	570°	1015°
Crown 516/640	810°	605°	485°	660°	1275°
Barion 614/564 . . .	840°	645°	575°	650°	950°
Barion 590/612 . . .	845°	645°	595°	730°	1000°

The various other properties of optical glasses were referred to briefly, mention being made of methods for determining durability and refractive index. Regarding the transmission of visible light, it was stated that in the case of a good borosilicate crown prism the light absorption through a glass path of 100 mm. was only 7 per cent., whilst in the case of a good plate glass it amounted to 30 per cent. of the incident light. The hardest glasses were the barium crowns, flint and plate glasses being the softest.

The author did not consider that very much greater advances were possible in the manufacture of optical glasses, and held that such advances would be confined chiefly to improved technical processes and the production of glasses freer from seeds and striæ and the exact reproduction of any particular glass in several successive meltings.

In the course of the discussion, the author stated that for normal altitudes the limiting diameter for telescopic objectives was 700 to 800 mm., the modern tendency being to have an opening of 600 to 650 mm. For reflectors a free opening of 1 m. was the limit. At higher altitudes, or in very dry climates, this could be increased, and at Mt. Wilson, America, a mirror opening of 2½ m. was employed.

J. H. D.

192. The "Standing-off" of Glass in Window Glass Factories. O. Fr. (*Sprechsaal*, 1922, **55**, 135).—With the idea of saving time, in many sheet-glass factories the glass was rapidly cooled before working out. When melting was complete, the air and gas were cut off, the chimney damper was opened wide, and the working openings were uncovered. Such procedure was not advisable since, in the first place, cylinders obtained from glass so cooled were often faulty. The process was also bad for both furnace and pots, whilst the saving in time was more apparent than real, since the strong pull of the chimney appreciably cooled the regenerative chambers, necessitating a longer period for heating up the furnaces. For mirror glass factories, where glass completely free from seed was desired, cooling should be very slow. In the case of window glass furnaces, after cutting off the air and gas, the working holes should be left covered and the chimney damper lowered for some time, to fine the glass completely. On then raising the damper and opening the working holes a much better glass would be obtained than if this had been rapidly cooled. A. C.

193. Stirring Molten Glass in Continuous Tank Furnaces. W. F. Brown, Charleston, W. Va., Assignor to Libbey Owens Sheet Glass Co., Toledo, Ohio (U.S.A. Pat., No. **1414008**, April 25th, 1922. Filed November 1st, 1920, No. 420883).—A stirring apparatus has been devised to remove cords and striæ formed in tank furnaces, especially when the temperature has been irregular.

The apparatus consisted of a stirring finger, 8, of porcelain or pot clay, carried on a downwardly projected stirring rod secured by a suitable elbow to the end of an operating rod, 10, passing through the wall of the furnace. Both the stirring rod and the operating rod were water-cooled. The manipulation of the rod, 10, might be performed by hand, or it might be driven from a motor as shown, in which case the length of stroke could be varied by securing the connecting rod, 20, to one or other of the bearings, 23. The rod, 10, was guided near its inner end by rollers, 24, mounted on a bracket on a furnace buckstay, 26, whilst near its outer end it passed through a sleeve, 27, pivoted to a bracket, 29. S. E.

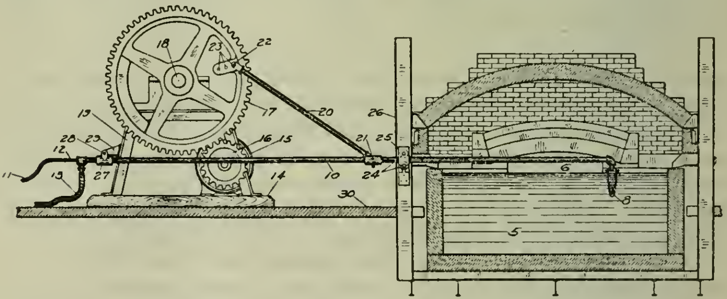

Fig. 129.

194. Cordy Glass. E. S. (*Sprechsaal*, 1922, **55**, 94).—Roof droppings were a frequent source of cords and were prevalent when the furnace had a firebrick, and not a silica, crown. Poor refractories resulted in increased pot and tank attack, producing a layer of high alumina content difficult to incorporate in the main bulk of the metal. Rings or boats of insufficient weight failed to sink below the surface of the glass and allowed surface impurities to pass within and be gathered. Sand, if not medium grained, or if of largely variable grain size, tended to produce cords. Too small a lime content gave a raw glass, addition of excess tended to produce devitrification, in both cases resulting in non-homogeneous glasses. Other batch materials tending to produce cordiness were aluminium and magnesium compounds, whilst boric oxide in large amounts caused increased pot attack and resulted in aluminous layers. In lead glasses, partial reduction of the lead compounds by reducing furnace gases or organic batch impurities gave streaks and cords. Bone ash glasses were particularly liable to cordiness if the opaliser was not carefully burned and finely ground, or if, after grinding, it was allowed to stand and so ball together. Insufficient mixing of the batch tended to uneven, cordy, glass, particularly if the latter was difficult to melt. Cullet was best if it approached in composition that of the glass produced by the batch, otherwise it needed grinding and mixing with the batch to produce a uniform melting. It was necessary to adjust the temperature of the furnace to suit the type of glass melted, difficultly fusible glasses requiring high temperatures to render homogeneous, but on the other hand great heat gave increased tendency to faults through attack on refractories. When glasses of varying degrees of hardness were melted in the same furnace it was necessary to charge in the softer glass at a later period, and the temperature of glasses first fined was then cooled somewhat by wholly or partly opening the pots. In cases where the pot was too cold on the first addition of batch, this portion remained incompletely fused at the bottom, and later produced impurities in the metal. This fault was particularly liable to occur in "Bütten" and similar furnaces, where tall pots were used. A further fault due to the addition of batch to a cold pot or tank was that this caused a cracking of the glazing, from which increased attack on refractories resulted. In tank furnaces incorrect bottom cooling was a frequent cause of cords. With glass of high metallic oxide content, too slow a change from the fluid to the semi-chilled state needed for working induced cordiness. Under-cooling during working out was the chief error which occurred in the manipulative period leading to the production of cordy glass. A. C.

195. The Flattening of Sheet-glass and Faults of the Process. O. Schrenk (*Sprechsaal*, 1922, **55**, 276).—Symmetrical, evenly blown cylinders were best for flattening, otherwise the process took longer to perform, the glass was unduly exposed to the action of the fire, and even then, in many cases, could not be well smoothed. A well-polished stone was essential.

When a new stone was heated up cracks developed, with sharp edges which scratched the glass. They were removed, before using the stone, by covering this with gypsum powder and rubbing with a smooth firebrick attached to an iron, a process occupying only a few minutes. Each time the stone was brought from the cooling chamber it was necessary to free it from pieces of glass and other foreign bodies which would adhere to the cylinder. For the same reason, it was necessary to sweep the crown of the furnace free from deposited ash before polishing the stone. A coating of water-glass on the crown prevented the fall of mortar from the joints. The water in which the flattening block was placed was often renewed to free it from dust, charcoal, etc., and the containing vessel regularly cleaned, since foreign matter adhering to the block scratched the glass. The block itself was made of soft alder, poplar, or willow, so cut that the sides used for flattening were free from knots. Before using, it was kept for some time in water. Cylinders were placed on the flattening stone by means of an iron, and this was kept free from scale and the portion coming in contact with the glass was rubbed with powdered gypsum. Similar treatment was given to the iron support on which the cylinders were brought to the flattening chamber. Cylinders, before being placed in the oven, were rubbed inside and out with a sponge cloth to remove impurities likely to scratch the glass, such, for instance, as the sawdust or charcoal spread inside to facilitate the springing open of the glass with the iron. By setting the flattening stone at too high a level above the cooling stone, the edges of the former scratched the glass as it was moved after flattening. In the case of badly blown cylinders, it was necessary to employ the iron to assist in opening out the cylinder, and in such circumstances faults were unavoidable. With strongly preheated cylinders, the iron used for placing these on the stone pressed into the soft glass and produced a hollow. A very rapid rate of working was dangerous, since it necessitated a very hot oven, and faulty cylinders which needed longer treatment were thus liable to stick to the stone, marking the glass and removing the polish from the stone itself. For preserving the polish of the stone, it was left to cool from ten to fifteen minutes after each time used. During the period of heating up the flattening oven much soot was deposited on the crown, and this was removed by cutting off the oven for fifteen minutes an hour before work commenced, after which time further admission of the flames was effective in accomplishing this purpose. If not removed, the soot flakes, falling on the glass and burning, rendered the material exceedingly brittle. Faults were caused by incorrect regulation of the heats of the cooling chamber and the lehr, and by a too rapid temperature gradient of the lehr itself. A preheating tube for cylinders was unnecessary, for not only did it take up valuable room, but it resulted in greater breakage, due to uneven heating up or to careless adjustment of the relative temperature of the tube and the flattening chamber. When such a tube was not used, small wooden pegs were placed at the ends of the slit, to keep the edges from falling together. These wedges, which burnt away in the oven, were made from wood left over from the manufacture of packing cases, and were well dried before use. A. C.

196. Faults in Glass, their Cause and Prevention. C. J. STAHL (*Glashütte*, 1920, **50**, 820; 1921, **51**, 19, 67, 84, 101, 148, 164, 180, 195, 212, 229, 245, 259).—A critical analysis, from a practical point of view, of the numerous types of faulty glass, with an indication as to likely causes in each part of the manufacturing process. A. C.

197. "Spit-out" of Glazes on Passing Through an Enamel Kiln. J. MILES (*Trans. Cer. Soc.*, 1921, **21**, 208).—"Spit-out" faults in pottery were caused by the bursting of small bubbles of gas at the surface of the glaze, leaving this with a more or less roughened surface.

The author described how "spit-out" could be produced intentionally and ascribed the trouble to the presence in the body of superheated steam at the temperature of the enamel kiln and its subsequent escape through the softened glaze. To remedy the defect it was necessary to have a well-fired glost oven and above all to guard against absorption of moisture in the warehouse or during decorating processes.

In an extended discussion it was generally agreed that the author's explanation was correct as being one cause of "spit-out," but that there were other causes quite as important which the author had ignored, the chief of these being the presence of organic matter in the pores of the body or glaze. This on oxidation in the enamel kiln gave rise to heated gases which burst their way through the glaze surface and caused "spits." J. H. D.

198. The Adsorption and Dissolution of Gases by Silicates. "Spit-Out." BERNARD MOORE and J. W. MELLOR (*Trans. Cer. Soc.*, 1922, **21**, 289).—"Spit-out" was one of the mysterious faults which occurred in the manufacture of pottery. Glazes when fired in the enamel kiln appeared to develop bubbles of gas which burst at the surface of the glaze.

A number of theories had been advanced to explain the phenomenon, some of which referred the fault to the glaze itself, others to the body.

Theories referring to Glaze.—1. A one-time popular theory of "spitting" was based on Seger's observation:* "A bisilicate glaze saturated with sulphates contains 4 per cent. of sulphur trioxide in solution, whereas a trisilicate under similar conditions contains only 2 per cent. Hence it follows that if a bisilicate, saturated with sulphates, dissolves more silica from the body, it can give up 2 per cent. of sulphur trioxide." This means that the greater the acidity of the glaze, the less its "carrying capacity" for sulphates.

The glaze might become more acidic: (*a*) By dissolving silica from the body, (*b*) by the volatilisation of lead oxide, (*c*) by the "sucking-up" of lead oxide by the body.

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* H. A. Seger, *Gesammelte Schriften*, Berlin, 1896, p. 509. Amer. translation, Easton, Pa., 1902, **2**, 646.

2. Stable sulphates in the glaze might be reduced to unstable sulphites which decomposed, giving rise to "spitting."

3. Glazes usually contained some bubbles; the bursting of these would give rise to spitting.

4. The authors experimented with pieces of frit, heating them in an atmosphere of coal gas, and showed that the fused silicates adsorbed a relatively large volume of hydrocarbon gases.

E. W. Washburn * found that all varieties of glass dissolved gases and this gas was liable to effervesce violently from the liquid glass if the pressure was reduced. Many observations on volcanic lavas, rocks, and minerals confirmed these results.

Considerable quantities of hydrocarbon vapours must be generated in the earlier stages of the firing of the muffles containing various kinds of pottery (ware decorated with oils, etc.). Under the temperature conditions the glazes would adsorb the gases.

If a glaze charged with hydrocarbon or combustible gases were heated in an oxidising atmosphere, the gases might burn below the surface of the glaze, whilst the heat developed would soften the glaze locally and thus facilitate "spitting."

5. In view of the fact that in the earlier stages of the firing of an enamel kiln much of the ware may be covered with a carbonaceous film and that a residue of carbon also remained for a considerable time after the volatile hydrocarbons had been driven off, solid carbon might diffuse into or be dissolved by the glaze.

The combustion of the carbon diffused into the glaze, together with the heat developed by the combustion, might give rise to "spitting."

6. Under certain conditions a glaze might take up an abnormal amount of gas and reject it in the form of "spits" on cooling.

Quite marked "spit," in addition to devitrification, might be developed on old glass when it was heated quickly after having been in contact with water for some time.

Theories referring to the Body.—1. Organic matter in the body might have been imperfectly oxidised in the biscuit oven; the entry of air during any subsequent firing might lead to the combustion of this organic matter and consequent "spit."

2. The body material (as described under the glaze theories) might adsorb gases in the kilns and ovens. If this were evolved after the glaze had been put on it would cause "spit."

3. Porous earthenware absorbed moisture, which it retained very tenaciously. Such ware, and in particular old ware, if fired in the enamel kiln was particularly liable to "spit."

In the authors' opinion, 80 per cent. of the spitting which occurred in the manufacture of pottery was due to the presence of moisture or organic matter in the "body."

A glass phenomenon which had been called the "Swinton Effect" appears to be a particular example of the general phenomena studied in this paper.

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* Univ. Ill. Bull., 1920, No. 118.

If the glass of a vacuum tube used with hydrogen, argon, helium, etc., were fused in the flame, it became clouded, and, under the microscope, was seen to be permeated to some depth from the inside surface with a multitude of minute spherical bubbles. Sometimes the glass of the melted tube appeared to boil and the bubbles could be seen and heard bursting.* There appeared to be four interpretations: (1) The bubbles were due to chemical action between the glass and the heated aluminium disintegrated from the electrodes (Pohl). (2) The gas passed into the glass by ordinary diffusion (J. J. Thomson). (3) The gas was evolved from the glass by chemical decomposition due to heat (F. Soddy and T. D. Mackenzie). (4) The gas was driven mechanically into the glass by the cathode rays. When the glass was heated the gas penetrated further and formed bubbles on cooling (A. A. C. Swinton). A. M. J.

199. The Process of Decay in Ancient Stained Glass. N. Heaton (*J. Roy. Inst. Brit. Architects*, 1921, **28**, 551).—The author protested against the use of the term "disease" as applied to the corrosion of glass as misleading, being likely to suggest that decay might spread from glass to glass by infection. Indeed, in non-technical literature such suggestions had been made. The actual cause of decay was well known, being due to lack of durability, just like modern glasses which contain excess of alkali. A good glass, well melted and prepared without the use of a large amount of alkali, could resist the corrosive effect of a moist atmosphere for many centuries. Whereas some of the glass in York Minster had become pitted and corroded very badly, the thirteenth-century glass in Westminster Abbey was still in a perfect state of preservation.

A typical composition of Roman and mediæval glass was: silica, 69; phosphoric acid, nil; soda, 17; potash, nil; lime and magnesia, 11; alumina, iron oxide, and manganese oxide, 3. An actual specimen from York Minster was found to have the composition: Silica, 53·85; phosphoric acid, 4·59; soda, 11·72; potash, 3·37; lime and magnesia, 20·07; alumina, iron oxide, and manganese oxide, 5·16; lead oxide, 0·59. W. E. S. T.

200. An Autoclave Test for Grading Chemical Glassware. W. L. Baillie and F. E. Wilson (*J. Soc. Chem. Ind.*, 1922, **41**, 45 T).—The paper described experiments to enable conditions for a pressure steam test to be specified for glasses of high durability used for lamp-working. The glasses were liable to exposure to water vapour and to prolonged storage before use. As great differences occurred in the pressures and temperatures employed by previous workers, the effect of pressure was studied. It was not found to be easy to calibrate the gauge in terms of temperature, as conduction took place through the metal of the autoclave, so results were expressed in pressures. The water used was distilled in a fume-free room and was checked for residues on evaporation.†

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* A. A. C. Swinton, *Proc. Roy. Soc.*, 1907, **79**, [*A*], 134; F. Soddy and T. D. Mackenzie, *ibid.*, 1908, **80**, [*A*], 92.

† Cf. this Journal, 1917, **1**, Trans., 175.

Iodoeosin was used in titrating alkalinity, and the conditions necessary to its successful use were found to be (*a*) sufficient ether to extract the iodoeosin from the aqueous layer when liberated from the alkali by the acid; (*b*) thorough and prolonged shaking after each addition of alkali; (*c*) solutions used cold to avoid evaporation of ether. The reactions of the solutions were :—

	Aqueous Layer.	Ethereal Layer.
Alkaline	Rose pink	Almost colourless
Acid..........................	Colourless	Orange

As it was found that carbonates could be quantitatively titrated with $N/500$-sulphuric acid by this indicator, the carbonation of alkaline deposits on glass was no obstacle to the determination of alkalinity. In practice, 20 c.c. of ethereal iodoeosin (5 mg. per litre) were added to the solution to be titrated in a 250 c.c. silica flask, $N/500$-sulphuric acid was added half a c.c. at a time with vigorous shaking, until the colour of the aqueous layer disappeared, and the excess titrated back with $N/500$-alkali, the volume of acid being corrected for the blank. Great care was necessary, but results could be duplicated to 0·20 c.c.

The test-pieces were prepared by washing successively with 5 per cent. cold aqueous acetic acid, water, alcohol, and ether, and drying for fifteen minutes at 50°.* Subsequent handling was carried out by means of platinum-tipped tongs. Tests for an hour at various pressures indicated 6 atmospheres as the lowest giving a definite separation of all the samples. Examination of the amount of alkali matter extracted at 6 atmospheres over varying periods showed the relative order of the samples to be the same for every period, in all cases but one.

The clouding of the samples was estimated as for the "Dimming Test," † and the order of merit was practically that indicated by the alkalinity test. Certain of the test-pieces cut from rod and tube had their ends rounded in a flame. This resulted in a belt of heavy cloud at the ends separated by a clear belt 0·25 inch wide, from the central clouded zone. Subsequent pieces were not so rounded off but were left as cut and precautions taken to keep them out of contact with fumes or dusty air.

Tables of changes in weight of the glasses after treatment bore out Schott's statement ‡ that the water absorbed at high temperatures cannot always be completely removed over sulphuric acid. The alkalies, especially potash, appeared to be the chief factors. The author concluded that water was present in the following states: (1) loosely associated as in hygroscopic moisture; (2) loosely combined as in hydrated silica, and, possibly, (3) strongly combined as in certain minerals which retain water until just below their melting points.

The residues after evaporation of the water and treatment with sulphuric acid followed by ignition for three minutes at 600°, were determined, but did not appear to lead to any definite relationship.

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* Cf. this JOURNAL, 1917, **1**, Trans., 175.

† Elsden, Roberts and Jones, this JOURNAL, 1919, **3**, Trans., 52.

‡ *Zeitsch. Instrumentenkunde*, 1889, **9**, 86.

Samples of the glasses were subjected to the "Dimming Test" of Elsden, Roberts, and Jones * and the alkalinity of duplicate samples was determined. The results of these two series of tests were in agreement with each other, but not with those of the autoclave tests. The divergence was ascribed to the effect of pressure on the reactions involved.

The order of hardness of the samples was stated to be the order of their $Al_2O_3+Fe_2O_3$ content.

It was shown that to reproduce results to within 5 per cent., the time of heating up to the pressure required, the time at that pressure, and the time taken to cool down must all be made the same for every test. In practice, the procedure was as follows. The cleaned and measured test-pieces of 3—4 sq. dcm. surface were placed on copper gauze in a silica beaker covered by a suitably perforated cap. The beaker stood on a perforated brass plate on a tripod so that the plate was just above the level of the water. A litre of ammonia-free water was used. The head of the autoclave was finally screwed down at 100°, as this was found to prevent leaks developing later. The pressure was taken up to 90 $lb./in.^2$ in fifty minutes and kept there for three hours. Steam was then blown off at once, and the pieces were removed when the temperature fell to 30° and allowed to cool under a bell-jar. They were then washed with cold ammonia-free water, the washings collected in a 250 c.c. silica flask, made up to the mark, and an aliquot portion removed for residue determination, the remainder being used for the iodoeosin titration with $N/500$-acid as already described.

The classifications suggested were—

(*a*) Resistance glass.—Alkalinity not greater than 0·3 mg. Na_2O per $dcm.^2$ Clouding no worse than A+.

(*b*) Durable.—Alkalinity 0·3—0·8 mg. Clouding B.

(*c*) Less durable.—Alkalinity 0·8—2·0 mg. Clouding B+.

(*d*) Soft, not suitable for laboratory use.—Alkalinity >2·0. Clouding B+ or worse. M. P.

201. A Study of Brown Glass Milk Bottles. A. W. BITTING (*Glass Container*, 1922, **1**, 14).—Tests were made on brown, and on clear glass bottles, and it was found that not only did the amber glass prevent detection of dirt and sediment in milk, but the quality of the milk was considerably reduced when stored in such bottles. The temperature attained by milk contained in the brown bottles was higher than that in the colourless ones, and the bacterial contents and acidity increased. On the other hand, the retention of flavour and colour was more satisfactory when the milk was kept in brown bottles. V. D.

202. The Absorption Spectra of Glasses of Various Compositions containing Didymium. F. WEIDERT (*Zeitsch wiss. Photographie*, 1922, **21**, 254).—The author conducted a spectrographic comparison of the absorption spectrum of didymium present as a solid solution in various glasses with that of aqueous solutions of the nitrate of didymium and other rare earths. He also investigated the effect of the composition of the glass on the absorption spectrum.

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* *Loc. cit.*

The didymium was added to eight of the glass batches in the form of a crystalline nitrate the percentage composition of which, after ignition, was Nd_2O_3 22·0, Pr_2O_3 12·5, Sm_2O_3 6·9, Ce_2O_3 20·2, La_2O_3 38·4.

To a ninth glass, melted only on a very small scale, pure neodymium oxide was added. The compositions of the glasses are given in the following table and are expressed in terms of the number of molecules of each constituent per one molecule of neodymium oxide.

Melting No.	SiO_2.	B_2O_3.	As_2O_5.	PbO.	Al_2O_3.	CaO.	K_2O.	Na_2O.	La_2O_3.	Ce_2O_3.	Nd_2O_3.	Pr_2O_3.	Sm_2O_3.
V 60	640	30	0·8	—	—	125	120	—	1·8	0·9	1·0	0·6	0·3
V 79	760	—	1·3	—	—	30	120	—	1·8	0·9	1·0	0·6	0·3
V 80	660	90	1·3	—	—	30	120	—	1·8	0·9	1·0	0·6	0·3
V 82	560	—	1·3	80	—	—	80	—	1·8	0·9	1·0	0·6	0·3
V 83	700	130	1·3	—	15	—	—	100	1·8	0·9	1·0	0·6	0·3
V 84	450	90	1·3	80	—	—	80	—	1·8	0·9	1·0	0·6	0·3
V 87	400	—	1·3	140	—	—	45	—	1·8	0·9	1·0	0·6	0·3
V 100	390	260	1·3	—	110	—	—	100	1·8	0·9	1·0	0·6	0·3
L 1035	420	—	1·0	60	—	—	60	—	—	—	1·0	—	—

In order to have the same concentration by weight of the rare earths, the thickness of the plates of glass examined was varied inversely as the density of the glass. As a standard for comparison, a glass of density 2·50 was taken and used in thicknesses of 10, 20, 40, and 80 mm. The other glasses were made in the form of plates of thicknesses corresponding with the four separate thicknesses of the standard glass. The volume concentration of the standard was 1·37 gm. of Nd_2O_3, 0·76 gm. of Pr_2O_3, and 0·42 gm. of Sm_2O_3 per 100 c.c.

The aqueous solutions employed for comparison included, not only a solution of the rare oxides in the proportions indicated in the table of compositions, but also solutions containing, respectively, the equivalent of 1·37 gm. of Nd_2O_3, 0·76 gm. of Pr_2O_3, and 0·42 gm. of Sm_2O_3 per 100 c.c.

The optical constants determined (other than the absorptions) were given as in the following table :

Melting No.	n_D.	$n_F - n_C$.	ν value.	Density.
V 60	1·5321	0·00884	60·2	2·56
V 79	1·4996	0·00810	61·7	2·43
V 80	1·5197	0·00811	64·1	2·51
V 82	1·5644	0·01287	43·9	3·08
V 83	1·5044	0·00786	64·2	2·43
V 84	1·5819	0·01291	45·1	3·17
V 87	1·6601	0·01972	33·5	3·95
V 100	1·4988	0·00820	60·9	2·31
L 1035	—	—	—	3·06

The absorption bands characteristic of the glasses were broader and less sharp than the corresponding bands afforded by the aqueous solutions. The presence of boric oxide in the glass increased the lack of sharpness in the bands. Lead–potash containing glasses afforded the sharpest bands.

Reproductions of certain of the absorption spectra were given, and the author discussed the shift of the bands in various cases.

F. W. H.

203. The Structure of Abraded Glass Surfaces. F. W. Preston (*Trans. Optical Soc.*, 1922, **23**, 141).—The author stated that the primary object of his paper was to substitute the conception of a flaw- or fissure-complex for the current view of a hill-and-hollow structure, as characterising a ground surface in brittle materials. The paper was illustrated with numerous photomicrographs to demonstrate the correctness of this view. The first showed the flaw produced when a steel ball was pressed against a plane glass surface. The development of the flaw as the pressure increased was described. "Chatter" flaws were next dealt with. These were produced when a chattering needle or non-rotating ball was moved over the surface of the glass under a pressure oblique to the surface. The complete sequence of flaws, or "chatter sleeks," consisted of a central series of hyperboloidal chatter flaws and two lateral series arranged in cascades down the sides. A given ball could not produce a sleek of less than a certain critical width, which increased when the pressure was increased to a limiting width about 30 per cent. greater than the original. At the same time, the distance apart of individual flaws decreased. The sleek produced by a rolling ball resembled that of a non-rotating ball, but in this case the flaws were concave to the direction from which the ball came. With increased pressure, longitudinal flaws appeared near the centre of the chatter flaws. The action of the glazier's diamond and glazier's wheel was complex, but the flaws produced were similar in some respects to those previously mentioned.

These considerations preceded a study of the structure of "grey" surfaces. In all these cases, very little material was removed. When a glass surface was ground, each grain of abrasive produced a flaw of one of the above types, depending on its individual smoothness and motion. Removal of material was held to commence when the flaws intersected in a number of directions. A series of photomicrographs of a fifteen-minute energy surface after etching for various lengths of time showed that, contrary to Lord Rayleigh's interpretation, the hollows did not originate in pits, but in flaws. The surface irregularities did not represent the full depth of the fractured layer. Below them a large number of flaws extended to a depth apparently two or three times as great. With the assistance of these results, the double refraction observed by Twyman near the surfaces of ground glass was explained, it being held that the strain was due to small particles of glass being forced into the flaws, wedging them open.

The second part of the paper was devoted to observations on etch attack. Bielby had demonstrated the presence of a "flowed" surface layer on polished glass, estimating the thickness at about 100 $\mu\mu$. French, however, had suggested that the thickness was of the order of 4000 $\mu\mu$, and experiments were carried out to test this. It was found that a "greyed" surface was attacked between two and three times as fast as a disc-cut surface and about eleven times as fast as a polished surface. A further series of experiments showed that if there were a surface layer 4000 $\mu\mu$ thick it did not differ in solubility from the massive material. Consideration of the depth of etching led to the conclusion that the surface tension layer was, at the most, 10 $\mu\mu$ thick.

The patterns produced by etching polished glass were found to depend on the polishing agents. Three chief types were illustrated, the glass having been polished with (*a*) rouge, (*b*) manganese dioxide, (*c*) chromic oxide. The patterns demonstrated that chatter sleeks were made by these agents, and a study of the sleeks showed that all the effective particles in the polisher were sliding, not rolling. The distance between the flaws in the sleek was of the order of 1000 $\mu\mu$, and the width of the sleek was about 3500 $\mu\mu$. In addition to these, there were other, web-shaped sleeks in which no structure could be made out. If these were also chatter sleeks their detail was of the order of 100 $\mu\mu$, and thus any flowing of the surface layer due to surface tension was very limited. Exceedingly fine abrasives polished very slowly and left no visible sleeks, but for ordinary use those abrasives which left a good web pattern were to be preferred. The polished surface of the glass under those conditions was a mass of tiny flaws, covered by an exceedingly thin flowed layer. The etch patterns of various types of glass did not differ, and the structure of polished quartz and felspar was similar. The structure on apatite and fluorite was different, resembling the grooves produced on metals by polishing powders. J. R. C.

204. Measurements of the Stress produced at the Surface of Glass by Grinding with Loose Abrasives. A. J. DALLADAY (*Trans. Optical Soc.*, 1922, **23**, 170).—The actual compressions in the grey surfaces produced on glass by grinding with various abrasives were measured and found to be as follows :—

Abrasive.	Size of Grain in 0·01 mm.	Thickness of Glass, mm.	Thrust in gm. per cm.
No. 80 Carborundum	40	3·24	680
No. 180 Carborundum	15	3·15	535
No. 200 Corundum	10—12	3·11	480
Naxos emery (fine trueing) ...	5	3·06	380
Naxos emery (smoothing)	2·5	3·04	300
Naxos emery (fine smoothing)	1·5	3·03	210

The stresses in a grey surface might affect the perfection of figure of the opposite surface. For example, a mirror, 1 inch in diameter and radius of curvature 1 metre, had its curvature reduced to 85 cm., when the back surface was greyed, and restored to 100 cm. by polishing the grey surface. J. R. C.

205. The Stress Conditions Surrounding a Diamond Cut in Glass. A. J. Dalladay and F. Twyman (*Trans. Optical Soc.*, 1922, **23**, 165).—The essential features of the stress system seemed to be a region of violent horizontal tension immediately below the diamond cut, changing abruptly into a compression which diminished very rapidly, being very slight at 2—3 mm. depth. By heating the glass (Chance's Hard Crown) to a temperature 60° or 70° below the annealing temperature, practically the whole of the stresses could be removed without disturbing the annealing of the block itself. In the discussion, F. W. Preston pointed out that the stresses could be explained by minute particles of glass wedging open the fissures made by the diamond. J. R. C.

206. Sodium Silicate. A. Erdenbrecher (*Mikrokosmos*, 1921, **15**, 55; from *J. Chem. Soc.*, 1922, **122**, ii, 444).—The addition of not more than 40 gm. of sodium hydroxide to 100 c.c. of the solution obtained when 20 to 25 gm. of the salt $Na_2SiO_3,9—10H_2O$ were dissolved in 40 c.c. of water yielded the hydrate $Na_2SiO_3,9H_2O$, in rhombic crystals of melting point 47°. Sixty grams of sodium hydroxide similarly yielded the hydrate $Na_2SiO_3,6H_2O$, monoclinic crystals of melting point 63·5°, whilst larger amounts of sodium hydroxide yielded the hydrate $Na_2SiO_3,4H_2O$, hexagonal crystals of melting point 83—85°. Other hydrates of sodium metasilicate mentioned in the literature were held to be probably mixtures of these, as changes in the composition of the mother-liquor caused changes in the degree of hydration. F. W. H.

207. Electrolysis of Sodium Silicate Solutions. J. F. Spencer and Kathleen Proud (*Kolloid Zeitsch.*, 1922, **21**, 36).—Orthosilicic acid was obtained at the anode by the electrolysis of a 50 per cent. sodium silicate solution, the kathode being a platinum dish and the anode a coil of platinum wire immersed in a porous cell. The product was glass-like, insoluble in water, stable in air, and, as it accumulated at the anode, produced an insulating layer. W. E. S. T.

III.—Lamp-worked and General Scientific Apparatus.

208. A Reagent Bottle Syphon. C. H. Jacobson (*J. Ind. Eng. Chem.*, 1922, **14**, 731).—The burette, *C* (Fig. 130), is amply supported by the stout glass syphon tube, *B*, which is firmly fixed through the stopper of the two-litre bottle, *A*. *F* is a removable

plug excluding dust when not in use. Liquid is syphoned over by opening *E*, compressing the rubber ball, *D* (similar to those on spraying bottles), and allowing it to expand again. By filling the entire tube up to the top of *B* it can be used as a plain syphon.
M. P.

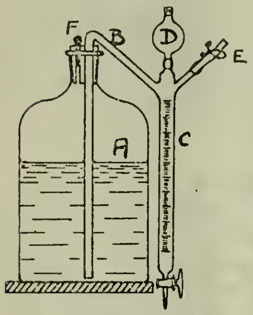

Fig. 130.

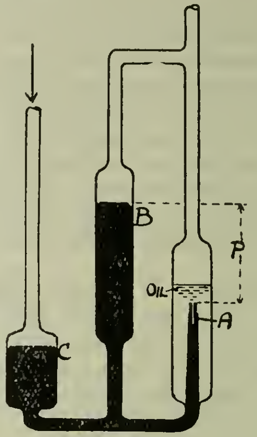

Fig. 131.

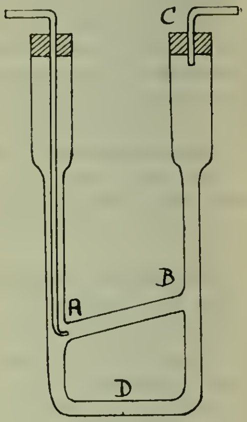

Fig. 132.

209. Apparatus for Determination of Interfacial Tension. R. E. Wilson and D. P. Barnard (*J. Ind. Eng. Chem.*, 1922, **14**, 689).—Pressure is applied *via C* (Fig. 131) until the mercury is forced through the capillary, *A*, which is below the oil. The interfacial tension between the mercury and the oil is calculated from the formula $\gamma=\frac{P.r}{2}\left(1-\frac{2}{3}\frac{dr}{P}-\frac{d^2r^2}{P^2}\right)$, *P* being the head of mercury necessary to force the drops to separate from the capillary *A*, *d*, the density of mercury, and *r*, the radius of the capillary.
M. P.

210. Absorption Apparatus. C. S. Imison and W. Russell (*J. Soc. Chem. Ind.*, 1922, **41**, 37 t).—The apparatus was designed to test the amount of ammonia gas in air from ammonia oxidation apparatus and works on the air-lift principle. It was made from tube $\frac{1}{4}$ inch internal bore, and the gas inlet was drawn to a capillary jet turned up at *A* (Fig. 132). In use, *C* was withdrawn and 5 c.c. of *N*- sulphuric acid added from a pipette, keeping the tip of the pipette below *B*. Care was taken that none of the acid was left on the walls between *C* and *B* by touching the pipette against them. An indicator having been introduced, *C* was replaced and a known volume of air under test aspirated through. The bubbles of air set up a circulatory motion of the liquid. Changes in colour were said to be so rapid that the liquid between *A* and *B* might be yellow and between *B*, *D*, and *A*, red (methyl-red as indicator), and 5 c.c. more gas aspirated through would cause the change. A further advantage was the small volume of acid absorbent required.
M. P.

211. Regulator for Electrically Controlled Thermostat. S. O. Rawlins (*J. Soc. Chem. Ind.*, 1922, **41**, 250 T).—The apparatus was filled with clean dry mercury through *H* until the level was about half-way up the constricted portion of the bore of *F*, and *G* was closed by an indiarubber tube and a clip. The toluene or saturated calcium chloride solution was then poured into the main bulbs through *K*. Adjustment was effected by heating up to the desired temperature with *K* open, shutting it, and setting the tip of the platinum wire in *F* just on the mercury surface. *D* was a seal in the U-tube, contact being made by a platinum wire fused through the obstruction. In electric control for which the above was designed, banks of carbon filament lamps as resistances were employed instead of the usual rheostats in series and in parallel. This was stated to facilitate greatly the change from one steady temperature to another, as, once the necessary combinations had been worked out, it was simply a matter of changing lamps in holders, as contrasted with the usual way of adjusting the rheostats until the desired temperature was attained.

M. P.

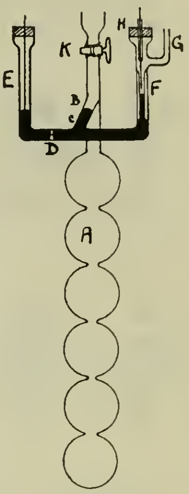

Fig. 133.

212. Report on Standardisation of Sizes and Shapes of Apparatus. W. D. Collins (*J. Ind. Eng. Chem.*, 1921, **13**, 1070; 1922, **14**, 654 and 738).—The report embodied the findings of a committee of the (American) Scientific Apparatus Makers' Association and of the (American) Committee on Guaranteed Reagents and Standard Apparatus.

The symbols R and D signify retain and discontinue, respectively.

Burettes.

All to be graduated as follows: 10 c.c. in 1/20 c.c. divisions; 25 c.c. in 1/10 c.c. divisions; 50 c.c. in 1/10 c.c. divisions; 100 c.c. in 1/5 c.c. divisions.

Discontinue the following: *For pinchcock* 10 c.c. capacity; *for pinchcock with side tube*, all sizes; *with straight glass stopcock and side tube*, all sizes; *with three-way stopcock*, 100 c.c. capacity; *with Fresenius stopcock*, 25 c.c. capacity; *with Fresenius stopcock and side tube with glass stopcock*, 25 c.c. capacity; *Gawalowski, straight glass stopcock, and side tube with glass stopcock*, all sizes; *Schellback, for pinchcock, with side tube*, all sizes; *Schellback, with three-way stopcock*, 25 c.c. capacity; *Dispensing, for pinchcock*, all sizes.

Adapters.

Discontinue: *Straight*, 250 *mm.* × 35 *mm.; and bent at* 45° *angle*, 250 *mm.* × 35 *mm.*

CALCIUM CHLORIDE TUBES.

The following sizes to be retained :

Straight, one bulb.

Cat. Spec., mm.	Length over all, mm.	Length to bottom of bulb, mm.	Inner diam. tube, mm.	Diam. bulb., mm.	Length of stem, mm.	Diam. of stem, mm.
100	140	100	14	25	40	6
150	190	150	16	30	40	6
200	240	200	18	32	40	6

Straight, two bulbs.

Cat. Spec., mm.	Length over all, mm.	Length to bottom of first bulb, mm.	Inner diam. of tube, mm.	Diam. top bulb, mm.	Length of stem, mm.	Diam. of stem, mm.
100	155	100	14	25	30	6
150	205	150	16	30	30	6
200	255	200	18	32	30	6

U-*Shape, plain.*

Cat. Spec., mm	Length over all, mm.	Inner diam. tube, mm.
100	100	14
150	150	16
200	200	18

U-*Shape, with side arms.*

Cat. Spec., mm.	Length over all, mm.	Inner diam. tube, mm.	Length side arm, mm.	Diam. side arm, mm.	Dist. below top, mm.
100	100	14	40	6	20
150	150	16	40	6	25
200	200	18	40	7	30

Schwartz, with side tubes and ground glass stoppers.

Cat. Spec., mm.	Length over all w/t stop., mm.	Inner diam. tube, mm.	Length side tube, mm.	Outside diam. side tubes, mm.
100	100	15	40	6
150	150	15	40	6

Straight with two bulbs, smaller having inner tube to trap moisture : 100 mm., 150 mm.

Volhard's U*-tube with side arms, one arm having a bulb to collect moisture :* 100 mm., 150 mm.

Marchand's U*-tube with permanent side tube :* 150 mm.

Peligot's U*-tube with 3 bulbs :* 100 mm., 150 mm.

Drying towers, for cork connections : 250 mm., 300 mm.

Drying towers, with ground stopcock, stopper, and connections for rubber tubing : 250 mm., 300 mm.

CONDENSERS.

Types to be retained :

Allihn's, with adapter sealed on : 200 mm., 300 mm., 400 mm., and 600 mm.

Hopkin's, total length 380 mm.

Liebig's, rubber connections, and adapter : 300 mm., 400 mm., 500 mm., 600 mm., 750 mm.

Liebig's, permanent seal, with adapter : 250 mm., 300 mm., 400 mm., 500 mm., 600 mm.

Liebig's, coiled condenser tube, with adapter : 200 mm., 300 mm., 400 mm., 600 mm.

DISTILLING TUBES.

To be discontinued :

With vapour inlet tube ; Knight's ; Le Bel-Henniger's, 2-bulb, 4-bulb, and 5-bulb ; *Wurtz's with* 2 *bulbs ; Young's with* 15 *disks.*

FLASKS, MISCELLANEOUS.

To be discontinued :

Erlenmeyer, ground glass stopper, resistance : 60 c.c. and 1000 c.c.

Assay beaker, resistance glass : 1000 c.c. size.

Distilling, Claissen's, angle 75° : 3 in. immersion, 10 c.c., 60 c.c., 2000 c.c.

Distilling, Ladenburg, 3 *bulbs :* all sizes.

Distilling, Ladenburg, Pyrex glass : all sizes.

Distilling, three necks, Pyrex glass : all sizes.

Distilling, Lunge, with trap : all sizes.

Elutriating, Benningsen : 400 c.c. capacity.

Extraction, resistance grade, flat bottom, wide mouth, vial neck : 60 c.c. size.

Extraction, round bottom, Pyrex glass : all sizes.

Filtering, Erlenmeyer form, heavy glass, side neck : 750 c.c.

Filtering, glass stopcock on side neck : 250 c.c. and 2000 c.c.

Filtering, side tube, funnel ground in neck : all sizes.

Gray's carbon residue, opaque fused silica : 50 c.c.

Joliet, for use in analysis of iron and steel : all sizes.

Kjeldahl, round bottom, long neck, resistance glass.

Kjeldahl, flat bottom, long neck : all sizes.

Kjeldahl, round bottom, short neck : 500 c.c.

Melting point and oxygen, Pyrex glass, long neck : all sizes.

Phosphorus, Erlenmeyer, narrow neck, resistance : 400 c.c.

Distilling, Tuttle, glass stopper : 1500 c.c.

Distilling, Anschütz : all sizes.

Distilling, Hempel, bent side tube, Pyrex.

Filtering, pear shape, side neck, heavy glass : all sizes.

Generating, thistle tube and delivery tube : all sizes.

Sulphur, Pyrex, Erlenmeyer : 500 c.c.

Sulphur, flat bottom, side neck, vial neck : all sizes.

Johnson's sulphur, Pyrex glass : 275 c.c.

Volumetric : 20 c.c. and 300 c.c.
Volumetric with glass stopper ground in : 20 c.c. and 300 c.c.
Volumetric, conical, enlarged mouth : capacity 100 c.c.
Volumetric, according to requirements of the Bureau of Standards, Pyrex, Sugar, Bates', pear shape : 100 c.c.
Shaking, unstoppered, heavy glass, graduated : all sizes.
Shaking, glass stoppered, heavy glass, graduated : all sizes.
Volumetric, graduated neck.

PYREX GLASSWARE.

Griffin beakers, lipped,

Sizes :	30 c.c. D	50 c.c. R	100 c.c. R	150 c.c. R	250 c.c. R
	400 c.c. R	600 c.c. R	800 c.c. R	1000 c.c. R	1300 c.c. D
	1500 c.c. R	2000 c.c. R	2500 c.c. D	3000 c.c. R	4000 c.c. R

Berzelius beakers, lipped,

Sizes :	100 c.c. D	150 c.c. D	200 c.c. D	300 c.c. D	400 c.c. D
	500 c.c. D	600 c.c. D	800 c.c. D	1000 c.c. D	

Griffin beakers, no lip,

Sizes :	30 c.c. D	50 c.c. D	100 c.c. D	150 c.c. D	250 c.c. D
	400 c.c. D	600 c.c. D	800 c.c. D	1000 c.c. D	1300 c.c. D
	1500 c.c. D	2000 c.c. D	2500 c.c. D	3000 c.c. D	4000 c.c. D

Berzelius beakers, no lip,

Sizes :	100 c.c. R	150 c.c. D	200 c.c. R	300 c.c. R	400 c.c. R
	500 c.c. R	600 c.c. D	800 c.c. D	1000 c.c. D	

Boiling flasks, flat bottom, vial mouth,

Sizes :	50 c.c. R	100 c.c. D	New size. 125 c.c. R	150 c.c. D	200 c.c. D
	New size. 250 c.c. R	300 c.c. D	400 c.c. D	500 c.c. R	700 c.c. D
	1000 c.c. R	1500 c.c. D	2000 c.c. R	3000 c.c. R	6000 c.c. R
	12000 c.c. No. 10 stop. D	12000 c.c. No. 13 stop. R	24000 c.c. D		

Boiling flasks, flat bottom, ring neck,

Sizes :	500 c.c.	700 c.c.	1000 c.c.	1500 c.c.	2000 c.c.
	R	D	R	D	R
	3000 c.c.	6000 c.c.			
	R	R			

Boiling flasks, round bottom, vial mouth,

Sizes :	100 c.c.	150 c.c.	200 c.c.	300 c.c.	400 c.c.
	R	D	R	R	D
	500 c.c.	700 c.c.	1000 c.c.	1500 c.c.	2000 c.c.
	R	D	R	D	R
	3000 c.c.				
	D				

Erlenmeyer flasks, narrow mouth,

Sizes :	25 c.c.	50 c.c.	100 c.c.	New size. 125 c.c.	150 c.c.
	D	R	D	R	D
	200 c.c.	New size. 250 c.c.	300 c.c.	500 c.c.	600 c.c.
	R	R	D	R	D
	750 c.c.	1000 c.c.	1500 c.c.	2000 c.c.	3000 c.c.
	D	R	D	R	R
	4000 c.c.	6000 c.c.			
	R	R			

Erlenmeyer flasks, wide mouth,

Sizes :	250 c.c.	500 c.c.	750 c.c.	1000 c.c.	2000 c.c.
	R	R	D	D	D

Filtering flasks, with tubulure,

Sizes :	250 c.c.	500 c.c.	1000 c.c.	2000 c.c.	4000 c.c.
	R	R	R	R	R

Filtering flasks, no tubulure,

Sizes :	250 c.c.	500 c.c.	1000 c.c.	2000 c.c.	4000 c.c.
	D	D	D	D	D

Flasks, round bottom, short ring neck,

Sizes :	200 c.c.	500 c.c.	1000 c.c.	1500 c.c.	2000 c.c.
	R	R	R	D	R
	3000 c.c.	5000 c.c.	12000 c.c.		
	R	R	R		

Balloon flasks, ring neck,

Sizes :	22 litre	50 litre	75 litre
	R	R	R

Balloon flask, without ring neck,

Size :	75 litre
	D

Kjeldahl flasks, round bottom, long neck,

Sizes :	300 c.c.	500 c.c.	650 c.c.	800 c.c.
	R	R	D	R

Extraction flasks, flat bottom, vial mouth,

Sizes :	50 c.c.	100 c.c.	150 c.c.	250 c.c.	500 c.c.
	R	R	R	R	R
	750 c.c.	1000 c.c.	2000 c.c.	3000 c.c.	
	R	D	D	D	

WEIGHING BOTTLES.

The following types to be retained :

Conical form, with flat bottom and ground glass stopper, capacities 15 c.c., 30 c.c., and 60 c.c.

High form, flat bottom, ground stopper, without neck, sizes :

	Mm.	Mm.	Mm.
Height	60	80	100
Diameter	15	15	25

Low form, flat bottom, ground glass stopper, without neck, sizes :

	Mm.	Mm.	Mm.
Height	50	50	60
Diameter	25	40	30

Extra wide form, flat bottom, without neck, ground glass stopper, sizes :

	Mm.	Mm.	Mm.
Height	30	30	30
Diameter	60	60	70

Parr's, with cover ground outside.

Grethen's form, with glass stopcock, weighing pipette, capacity 2 c.c.

Lunge's weighing pipette, with two stopcocks, capacity 15 c.c.

CYLINDERS.

Hydrometer jar with lip, heavy glass on foot :

Height, inches :	4	5	5	5	5	5	6	6
Diameter, inches :	1	¾	1	1¼	1½	2	1	1½
	D	D	R	D	D	D	R	R

Height, inches :	6	8	8	10	10	12	12	12
Diameter, inches :	2	1½	2	1½	2	1½	2	3
	D	R	D	R	D	R	R	D

Height, inches :	14	14	15	15	18	20	20	22
Diameter, inches :	2	2½	1½	2	2½	2	2½	3
	D	D	D	R	R	D	D	R

Height, inches :	18
Diameter, inches :	3
	D

Heavy glass ring neck ; on foot, discontinue all sizes.

Hydrometer jars, heavy glass, with flange ground to take glass plate :

Height, inches :	6	8	10	12	12	15	15	18
Diameter, inches :	1½	1½	1½	2	4	2	3	3
	D	D	R	R	D	R	D	R

Hydrometer jars, with enlarged top :

Height, inches :	12	12	14	14	16	16
Diameter, inches :	1½	2	2	1½	2½	2
	R	D	R	D	D	R

Graduated, for Brown-Duvel moisture tester, graduated to 25 c.c. in 0·2 c.c., retain.

Graduated, with single graduations :

Capacity, c.c. :	5	10	15	25	50	100	200	250
	R	R	D	R	R	R	D	R
	300	500	1000	2000	3000	4000		
	D	R	R	R	D	D		

Graduated, with double graduations, to read up and down. Subdivisions according to the Bureau of Standards :

Capacity, c.c. :	5	10	25	50	100	200	250	300
	R	R	R	R	R	D	R	D
	500	1000	2000	3000	4000			
	R	R	R	D	D			

Graduated in ounces and fractions, single graduations, lipped :

Capacity, ounces :	1	2	4	8	16	32
	D	D	D	D	D	D

Graduated and stoppered, single graduations :

Capacity, c.c. :	5	10	25	50	100	150	200	250
	D	R	R	R	R	D	D	R
	300	500	1000	2000	4000			
	D	R	R	R	D			

Graduated and stoppered, double graduations, to read up and down :

Capacity, c.c. :	5	10	25	50	100	200	250	300
	D	R	R	R	R	D	R	D
	500	1000	2000	4000				
	R	R	R	D				

DISHES.

Evaporating, glass, round bottom, with lip :

Sizes, mm. :	50	60	70	80	90	105	125	150
	D	D	D	D	D	D	D	D
	200							
	D							

Evaporating, glass, flat bottom, with lip :

Sizes, mm. :	50	60	70	80	90	100	125	150
	D	R	R	R	R	R	R	R
	170	200						
	D	R						

Opaque fused silica, glazed throughout :

Capacity, c.c. :	25	45	80	90	100	200	400	500
	D	R	R	D	R	R	D	D

Opaque fused silica, not glazed : discontinue.
Opaque fused silica, flat, glazed throughout with lip :

Capacity, c.c. :	20	30	75	150
	D	R	R	D

Opaque fused silica capsule :

Capacity, c.c. :	10	15	20	30	35	40
	D	R	R	D	R	D

Opaque fused silica capsule for ashing, capacity 40 c.c., retain.
Opaque fused silica capsule, large size, capacity 75 c.c., diam. 82 mm., depth 25 mm., retain.
Fused silica, incinerating :

Capacity, c.c. :	7	20
	D	D

FUNNELS.

Glass, Bunsen, with exact angle of 60°, ground rim, long stem :

Diam., mm. :	25	40	50	65	75	90	100	125	150	175	200	225	250	300
Length stem, mm. :	150	150	150	150	150	150	150	150	150	150	150	150	150	150
	R	R	R	R	R	R	R	D	D	D	D	D	D	D

With constrictions in stem : diam. mm. 50, 65, 75, 90, 100 (D).
Glass, nest of 3 *:* one of each $\frac{7}{8}$ in., 1 in., and $1\frac{1}{8}$ in. diam. (D).
Glass, without stem : Diam. mm. 75, 90, 100 (R).
With bulb in stem : Diam. in. $4\frac{1}{2}$, $5\frac{1}{2}$, 7 (D).
Glass filters, so-called carbon filters : Diam., mm. inside, 25, 28, 32, and 37 (R).
Glass ribbed :

Diam., in. :	$2\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	$4\frac{3}{4}$	$5\frac{3}{4}$	$7\frac{1}{4}$	$8\frac{3}{4}$	$10\frac{1}{4}$	13
	D	D	R	R	R	R	R	R	R

Ribbed, without stem : Diam. in. $2\frac{3}{4}$, $3\frac{3}{4}$, $4\frac{3}{4}$, $5\frac{3}{4}$ (D).
Glass, with deep conical corrugations : Diam. cm. 7, 9, 16, 20, 24 (D).
Glass, Spencer, with rubber ring (D).
Hot water or steam, plain glass, double jacketed (D).
Separating, Carnot's : capacity 200 c.c. (R).
Separating cylindrical, open top, glass stopcock, long stem : capacity c.c. 30, 250 (D); 60 and 125 (R).
Cylindrical, glass stoppered :

Capacity, c.c. : (plus 20% overage)	30	60	125	250	300	500	600	1000	1250
	D	R	R	R	D	R	D	R	D

500 c.c. and 1000 c.c. sizes to have short stems.

Cylindrical, glass stoppered, with side neck : capacity c.c. 300, 600, 1000 (D).

Separating, funnel shape, 60°, *heavy glass, with stopcock :*

Capacity, c.c. :	125	250	500	1000	2000	4000
Diam., mm. :	—	100	150	180	—	—
	D	R	R	R	D	D

Separating, globe shape, light glass, stoppered, stopcock with long stem : capacity c.c. 30, 60, 125, 250, 500, 1000 (R); 2000 (D).

Ditto, heavy moulded glass, and short stem : capacity c.c. 500, 1000, 2000, 4000 (R).

Squibbs, pear shape : capacity 125, 250, 500 (R); 1000 (D).

Separating, Strauss : capacity 30 c.c., without stopper (R).

For sulphonation test of creosote : 125 c.c. (R).

Walter, to deliver single drops : 60 c.c. (R).

Shaking, for phenol in creosote (D).

Thistle top, glass stoppered : capacity c.c. 30, 60, 125, 250 (D).

Separating, bell shape, open top : capacity c.c. 30, 125 (R).

C. M. Johnson, globe shape, long stem, open, with rod stopper : capacity c.c. 500, 1000, 2000, 4000, 8000 (D).

Sulphur, heavy glass, angle 60° (D).

Funnel tubes, thistle top, straight :

Length, cm. :	20	30	40	45	50
	D	R	R	D	D

Funnel tubes, conical top : length cm. 30 (R); 25, 40, 45, 50 (D).

Safety, thistle top, with bend : length cm. 30 (R).

Safety, conical top, with bend (D).

Safety, with bulbs, thistle top : No. of bulbs, 1, 2, 3 (R).

Ditto, with conical top ; with bulbs : 1, 2, 3 (D).

Vogel, funnel and delivery tube, combined (D).

Funnel tube, heavy, short stemmed, with bend and two bulbs for use with gas generator : sizes, small (D), large (R).

PIPETTES.

Automatic, dropping, rubber bulb : delivery exactly 1 c.c. (D).

Automatic, overflow, patent 3-way stopcock, reservoir for collecting excess ; ground connections : sizes, c.c. 10, 25, 50, 100 (D).

Ditto, capacity 17·6 *c.c., for milk testing* (D).

Ditto, rubber connections : sizes, c.c. 10, 25, 50 (R); 100 (D).

Calibrating, Ostwald's : capacity 2 c.c., sizes, c.c. 1 (D); 2 and 5 (R).

Capillary, graduated at 1/100 *c.c.* (R).

Dropping, medicinal, rubber bulb : length 4 in., tip straight or curved (R).

Mercury, for small drops (D).

Mohr, graduated in c.c., and fractions, glass stopcock : sizes, c.c. 25, 50 (D).

Delivery, Ostwald, in determination of N, *urea, and* NH_3 *in urine by Folin method :* sizes, c.c. 1, 2, 3, 5, 10 (R).

Without bulb, as used in bacteriological work, and H_2O *analysis:* sizes, c.c. 1, 5, 10 (R).

Wassermann safety (R).

Water analysis, as used in Hygienic Laboratory, U.S. Public Health Service: sizes, c.c. 2, 10, 11 (R).

Syphon, Struthers: c.c. 25, 50 (D).

Straight, drawn to point: length, in. 6, 7, 10, 15, 18 (D); 8, 12 (R).

Ditto, rubber bulb, of 25 c.c. capacity: length, in. 8, 12 (R); 6, 7, 10, 15, 18 (D).

Ungraduated, with bulb: capacity, c.c. 1, 2, 5, 10, 25, 50, 100, 200 (D).

Volumetric, accurately graduated: capacity, c.c. 1, 2, 5, 10, 20, 25, 50, 100, 200 (R); 3, 4, 12½, 15, 30, 75 (D).

Ditto, short form: capacity, c.c. 5, 10, 25 (R); 1, 2, 20, 50, 100, 200 (D).

Mohr, accurately graduated in c.c. and fractions:

Capacity, c.c.:	2/10	1/10	1	1	2	2	2	5
Subdivisions, c.c.:	1/100	1/100	1/100	1/10	1/50	1/10	1/20	1/100
	D	R	R	R	D	R	D	D
	5	5	10	10	20	25	50	50
	1/20	1/10	1/10	1/20	1/10	1/10	1/10	1/5
	R	R	R	D	D	R	D	D
	100	100						
	1/5	1/10						
	D	D						

Mohr, graduated to tip, serological:

Capacity, c.c.:	1/10	2/10	1	1	2	2	5	5
Subdivisions, c.c.:	1/100	1/100	1/100	1/10	1/10	1/20	1/10	1/20
	R	R	R	R	R	D	R	D
	25	50	50	100	10	10		
	1/10	1/5	1/10	1/10	1/10	1/20		
	D	D	D	D	R	D		

Automatic, Bailey, with stand, graduated: c.c. 10, 25, 50, 100 (D).

Ditto, Bleckman, with reservoir, stand: capacity, c.c. 5, 10, 25 (D).

Automatic, G. and F.: capacity, c.c. 10, 25, 50, 100 (D).

Automatic, Le Docte (D).

Donnan (D).

Mercury, for taking up mercury (R).

Overflow, Rickett, for silver assay (D).

Rothe (D).

Safety: capacity, c.c. 2, 5, 10, 25, 50, 100 (D).

Bottle, with capped pipette ground into neck, with pipette: c.c. 10, 25, 50, 100 (D).

Glucose, Spencer: 50 c.c. graduated 5—20° Brix., in 1/5° (R).

Sucrose: capacity, 52·096 c.c. graduated 5—25° Brix., in 1/10° (R).

STOPCOCKS.

Glass, for attaching to burette: bore 2 mm. (R).

Geissler: bore of stopper, mm. 1, 2, 3, 4, 5, 6, 8, 10 (R).

With capillary tube 6 to 7 mm. for gas analysis connections: 1½ mm. bore (R).

Geissler, bent : bore of stopper, mm. 1, 5, 10 (D); 2, 3, 4 (R).
With oblique bored stopper : bore mm. 2, 4 (R).
With oblique bored stopper, with capillary tube : 1½ mm. bore (R).
Three-way : bore of stopper, mm. 1 (D); 2, 4 (R).
Three-way, with capillary tube : 1½ mm. bore (R).
Three-way, with downward inlet, plug bored at angle : bore of stopper, mm. 2, 4 (R).
Ditto, with capillary tube : 1½ mm. bore (R).
Geissler, three-way : bore of stopper, mm. 1 (D); 2, 4 (R).
Ditto, downward inlet : bore, mm. 1 (D); 2, 4 (R).
Ditto, downward inlet, rubber connection below stopper : bore of stopper, mm. 2, 4 (D).
Four-way : bore, mm. 2, 4 (R).
Heavy glass, with bib : bore of stopper, mm. 3, 5, 8, 10 (D).
Two-way, mercury seal, plug bored at an angle : bore, mm. 2, 4 (D).
Fresenius form, for burette tips (R).
With inlet tube bore, 5 mm., outlet bore, 2 mm.

The Report also deals with potash and other absorption bulbs, alkalimeters, colour comparison tubes, extraction apparatus, gas generators, gas analysis apparatus, and special bottles. V. D.

213. Glass-metal Solder. (*Glasindustrie*, 1922, **8**, 63).—The side of the glass to be soldered was warmed, and neutral platinum chloride mixed with camomile oil applied by means of a brush, the oil being allowed to evaporate slowly until no more white vapour was given off, when the temperature was raised to dull red heat. The glass was put into a bath of copper sulphate, joined to the negative pole of a battery, and a copper deposit obtained. By means of the metal copper the glass could be soldered to iron, and by means of tin to copper. W. C. S.

IV.—Decorated Glass.

214. A Method of Producing Ornamental Articles. R. W. Schmidt, Chicago, Illinois (U.S.A. Pat., No. **1403268**, January 10th, 1922. Filed March 19th, 1920, No. 367259).—This invention has for its object the placing of an ornament or design under a transparent body and uniting the various parts into an integral structure by fusion.

In making a stud by this process, the glass shank has its end softened and flattened, and a layer of coloured glass is laid on the flattened portion. While this coloured glass is still plastic, small pieces of gold stone are laid on and sunk into it. This is then covered by a layer of clear glass and the whole reheated until the various layers have fused together into one solid mass. S. E.

215. The Painting and Burning of Serviette Rings. W. Hannich (*Glashütte*, 1922, **52**, 49).—Painting was performed separately from the other work, usually in an ordinary dwelling. The colour was laid on by means of a small brush, the ring meanwhile being held in the hand or in a wooden holder. Earth colours were employed mixed with linseed oil and powdered glass as a flux. Heating was performed in a special muffle furnace, free from fume and at a uniform rate. In the furnace, 3 or 4 muffles were placed directly one above another, the lowest just over the furnace hearth. In the upper muffles the rings were preheated, in the lower the glaze was softened. Muffles were obtainable for this purpose of a size 65×35×10 cm. and having two plates of 25 to 30 cm. diameter with rims. The muffles were placed at a distance of 10 to 12 cm. apart. Heating up was slow, the best temperature for burning being one in which the muffle was bright red. Although it was actually dependent on the colours used, the fusing temperature was usually about 650°. A. C.

V.—Optics and Optical Instruments.

216. Note on the Thin Astigmatic Lens. T. Chaundy (*Trans. Optical Soc.*, 1921, **23**, 56).—A mathematical note on the normal refraction of an aspherical wave front at an aspherical surface. J. R. C.

217. Note on Determining Prism Angle Errors. W. F. C. Ferguson (*J. Optical Soc. Amer.*, 1922, **6**, 108).—A note on the projection method of studying the deviation produced by a Dove erecting prism (see also this Journal, 1921, **5**, Abs. No. 317). J. R. C.

218. The Dispersion of Glass. T. Smith (*J. Optical Soc. Amer.*, 1922, **6**, 57).—The formulæ deduced by the author and by F. E. Wright (this Journal, 1921, **5**, Abs. Nos. 315 and 316) led to divergent conclusions on the possible properties of achromatic lenses. They were therefore examined to see which fitted the facts most closely. According to Wright, the secondary spectrum could be removed by a suitable choice of glasses if the curvatures of the first and last surfaces were equal, and it was shown that this was not possible. The constants involved in both formulæ were evaluated for a large number of glasses, and the conclusion drawn that the author's formula was preferable, although the other gave better results for some unstable glasses. J. R. C.

219. Invariant Ratios and Functions in Glass Dispersion. P. G. Nutting (*J. Optical Soc. Amer.*, 1922, **6**, 109).—Wright's investigation of the relations between the partial dispersions of optical glasses indicated that any partial dispersion such as $n_F - n_C$

was sensibly a linear function of any other such as $n_D-n_{A'}$, but the ratio of the two was not quite invariant for all glasses. It had been suggested that there might be some unique dispersion function to which the many already advanced were only approximations. The author mathematically examined this suggestion and showed that whilst a relationship as proposed by Wright might be of assistance in mixing glass batches and in selecting glasses for lens systems, it did not indicate any specific dispersion formula.

J. R. C.

220. Constructional Data for a Cemented Objective of Barium Crown and Flint. I. C. Gardner (*J. Optical Soc. Amer.*, 1922, **6**, 379).—Tables of data were given to facilitate the construction of cemented objectives of short focal length corrected for a large relative aperture. The tables were obtained by interpolation from a selected series of objectives. Table I gave the values of n_C, n_D, and n_F for two series of barium crowns, each series ranging from $n_D=1{\cdot}570$ to $1{\cdot}580$, and for a medium flint, $n_D=1{\cdot}610$ to $1{\cdot}622$. Tables 2, 3, and 4 gave the first, second, and third radii for an $F/5$ lens of unit focal length corrected for spherical and chromatic aberration. Table 5 gave the departures from the sine conditions of these lenses. Tables 6, 7, and 8 corresponded with 2, 3, and 4, except that in the case of this series spherical aberration was eliminated and the sine condition satisfied. Table 9 indicated the axial chromatic aberration of this series. A series of figures showed the errors in a typical lens constructed from the data. J. R. C.

221. The Path of Rays in Periscopes. A. Gleichen (*Trans. Optical Soc.*, 1921, **23**, 24).—The periscopes considered were those having an inverting system comprising two separated lenses. The author dealt very fully with the tracing of essential rays through the principal elements of the periscope and the best arrangement of these elements. In addition to tracing the rays, the author derived an expression for the illumination of the marginal beam in terms of the square of the diameter of the exit pupil. Special cases were treated : (*a*) when the length, the field of view, and the exit pupil were specified; (*b*) when it was necessary to reduce the diameter at the objective end. J. R. C.

222. A Criticism of the Nodal Slide. T. Smith and J. S. Anderson (*Trans. Optical Soc.*, 1922, **23**, 188).—In any lens system in which there was a considerable axial displacement between the entrance and the exit pupils on the one hand and the nodal points on the other, the defects of the nodal slide were great. The authors suggested modifications of the nodal slide to eliminate these defects. J. R. C.

223. The Barr and Stroud 100-feet Self-contained Base Range-finder. J. W. French (*Trans. Optical Soc.*, 1922, **23**, 175).—A special point about this range-finder was its new type of triple field. The object was viewed by a central telescopic system having an angular width of 1° 30′ and a highest magnification of 28 diameters. In the centre of the field of this system were the two range-finding fields which had an angular width of seventeen minutes. The mounting of the range-finder was described in detail and a diagram of the complete optical system given.

J. R. C.

224. Apparatus Exhibited at the Société Française de Physique. (*Revue d'Optique*, 1922, **1**, 265).—This exhibition of optical and other apparatus was held in April, 1922. It included a new polarimeter and saccharimeter which were claimed to be improvements on Laurent's forms of these instruments. The advantages and disadvantages of Laurent's apparatus were discussed. Various spectrometers, photometers, microscopes, and telescopes and an improved projection lantern were also shown and a description was now given. J. R. C.

VI.—Illumination and Illuminating Ware.

225. The Lighting of Public Buildings. E. H. Rayner, J. W. T. Walsh, and H. Buckley (*Illuminating Engineer*, 1922, **15**, 107).—The problem under investigation was the lighting of large rooms (170 feet by 37½ feet with the ceiling crossed by girders 15 inches deep, dividing the rooms into ten bays) intended for use by a clerical staff.

The average illumination of the whole room was determined as the mean of about a hundred measurements taken with a lumeter or a luxometer along certain definite lines.

Observations were also made of the surface brightness of the visible light sources and the reflection ratios of the decorations.

The values given by sixteen different installations with various decorations were given graphically in the paper, together with details of the fittings. Cost of power, uniformity of illumination, cost of maintenance (fittings and decorations), together with the initial cost of installation, must all be taken into account.

As a result of considering installation costs, the cost of current, renewals, and decorations over a period of five years, H.M. Office of Works was led to the adoption of an installation scheme described as Installation II (a semi-direct method) in conjunction with the decoration scheme, ceiling white (80 per cent. reflection ratio), walls light buff (60 per cent. reflection ratio), frieze white (80 per cent. reflection ratio). Twenty-six 14-inch opal bowls using 150-watt lamps were spaced alternately two and one in each bay, the rim of the bowls being 3 feet from the ceiling. The average initial illumination was 4·15 foot-candles, whilst the maximum and minimum were 5·5 foot-candles and 2·9 foot-candles, respectively. A. M. J.

VII.—Fuels, Refractories, and Furnaces.

226. Combustion of Fuel Oil; with a Description of an Oil-Gas Furnace. P. J. Woolf (*Trans. Cer. Soc.*, 1921, **21**, 161).—In a brief introduction, the author explained clearly the principles relating to combustion generally and concluded: "Mixing therefore is the basis of proper combustion and gasification of the fuel permits the best possible mixture." Dealing with methods of bringing about gasification, the author pointed out that in the case of solid fuels this could be brought about by means of a gas producer, preferably with an air–steam blast. The lighter petroleum products could readily be gasified exterior to the combustion chamber by means of an air-blast, and the heavier products had been used in gaseous form through a distillation process. The gasification of coal or heavy petroleum products required expensive apparatus beyond the equipment required to consume the gases.

Fuel oil, the petroleum residue after the distillation of the naphtha, had a fairly constant average composition of about 86 per cent. carbon, 12 per cent. hydrogen, and 2 per cent. other materials such as sulphur and ash. It had a calorific value of from 18,500—20,000 B.T.U. per lb. Below 200°, the vaporisation of the oil was practically negligible, but increased with rise of temperature till at 450° the oil was completely vaporised except for a small quantity of solid (less than 1 per cent.).

The use of heavy oil as a fuel was dependent on its being brought into intimate mixture with the air for combustion. In the earlier methods, this was brought about by spraying or "atomising" the oil by means of a current of air under pressure, but however finely the oil was sprayed it would not yield such an intimate combustion mixture with air as if the oil were in the gaseous form and consequently combustion took place more slowly.

The rate of ignition was also dependent on the velocity at which the oil spray was projected into the furnace, and in small furnaces this velocity could be such that combustion was not complete by the time the gases left the furnace unless a considerable amount of excess air was employed. Excess air led to lower temperatures being attained and consequently lower heat results and increased fuel consumption.

Velocity was given to the injected air, (1) to break up the stream of oil into fine spray, (2) to ensure the carrying of the liquid particles of oil in the spray without dropping, and (3) in some instances to inject additional air for combustion. It had the disadvantages that (1) it tended to carry the combustion to a particular part of the furnace, resulting in unequal heat distribution; (2) it resulted in incomplete combustion unless in large furnaces; (3) it might lead to erosion of the furnace walls through the impact of the liquid particles.

To remedy some of these disadvantages of the spray type of burner a "combustion chamber" had been added, separate from the heating chamber and about one-third of its size. The disadvantages attached to the separate combustion chamber were (*a*) the greatest heat was developed in the combustion chamber and not in the heating chamber, and (*b*) the increased size of the furnace.

To eliminate excess air and yet obtain perfect combustion without increasing the size of the furnace, the vaporisation and mixing of oil and air prior to its entry into the furnace was accomplished by the Sklovsky Patent.* The air was pre-heated and forced from the pre-heating chamber through the vaporising chamber. The necessary fuel oil, introduced in a stream of hot air into the latter chamber, vaporised completely, and the vapour, intimately mixed with air, conducted directly into the furnace. The temperature of the air–vapour mixture should be 350—400° and its velocity through the conducting pipe such as to prevent any recession of the flame back into the vaporiser. It was claimed that by this method complete combustion was attained without excess air and consequently higher temperatures and more rapid heating could be obtained.

The Oilgas Compensating Furnace was then described. ' It was a twin-chamber furnace in which the goods passed through the two sets of chambers in opposite directions. The heating zone was in the centre and cold stock entering in one set of chambers was pre-heated by the waste heat in the hot fired ware proceeding to the exit in the second set of chambers.

The kiln was stated to be adapted for firing any type of clay-ware, annealing sheet steel, steel, or iron castings, etc.

Amongst the numerous advantages claimed for this kiln were large reductions in fuel costs, saving of floor space, ease of control, and regularity of results. A critical discussion followed.

J. H. D.

227. Oil Firing in Glass-works Practice. H. MUHLERT (*Sprechsaal*, 1922, **55**, 3).—Fuel oil was generally brought to the works in tank-wagons or boats, whence it was pumped by geared pumps or plunger pumps into the main reservoir. This container held enough oil for about four weeks' supply, and in larger works was of two or three parts, to allow of cleaning while in use. Iron containers were better than ferro-concrete ones, which tended to crack, and they were built on the ground, or partly let into it. Easily replaceable filters were placed under the pipe leading to the pump. The oil container was provided with steam coils about 10 cm. from the bottom, to mix the heavy sediment, so preventing choking, and giving a richer burning oil. Care was necessary in laying the heating coils, since leaky joints allowed of the condensation of water in the oil. In the factory itself was a container holding one day's supply of oil, situated 4 to 6 m. above the floor. Better control was obtained by separating the oil used for melting furnaces from that used in other furnaces. These containers also were provided with steam coils, whilst a float and indicator was also needed. The daily supply tanks were filled from the main containers by means of a hand pump, or, in large works, by an electrically driven geared pump. Atomisers were the most suitable type of oil burners for glass-melting furnaces. The Körting steam-atomiser (Fig. 134) had the advantage of being easily built in or removed. Fig. 135 illustrates a form of atomiser suitable for either air or steam. The above two burners had the advantage that the deposition of carbon and choking up of the nozzle was prevented. It was usual to change the burner after eight days, but one of the second type had actually been employed for three weeks without cleaning. Low-pressure burners of the Schmidt pattern, working under an air pressure equal to 360 mm. of water, were quite suitable for lehrs or small melting furnaces. Pre-heating of the secondary air was important, and the author recommended an arrangement as indicated in Fig. 136 for a tank furnace with atomiser, recuperation here being employed. In regenerative furnaces, the effect of the reversal was troublesome, necessitating removal of the burner. In this case, the Körting atomiser was advantageous, since the exit opening could be closed without interfering with oil and steam inlets, and the burner could be removed and the furnace opening closed by a firebrick. Only

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* U.S. Pat., No. 1229338.

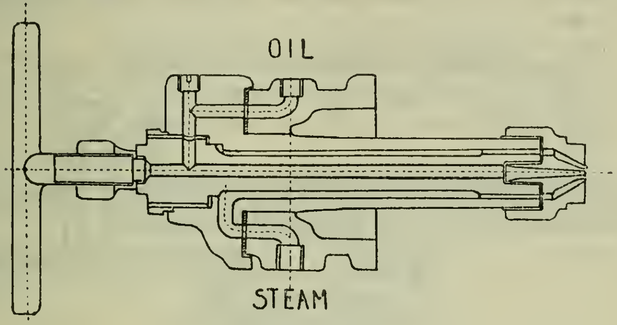

Fig. 134.

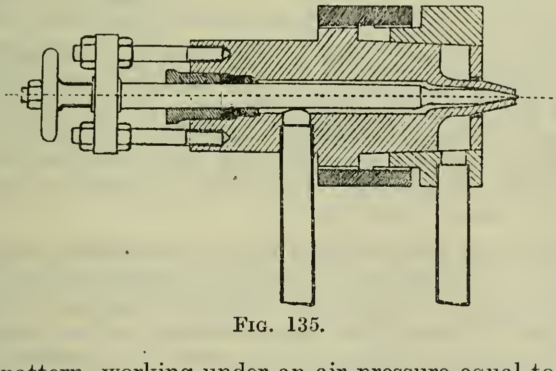

Fig. 135.

in small furnaces using low-pressure burners was the outlay less costly than when producers were employed. Oil transport, however, was less difficult than that of coal and ash, whilst the employment of oil eliminated the work of "poking," necessary when producers were used. For a daily production of 10,000 kg. of glass, 5000 kg. of oil were needed. About 14 cubic metres of secondary air, of which 10 per cent. was pressure air, were required for 1 kg. of oil. Thus in the above case, $\frac{5000}{24}\times 1{\cdot}4=300$ cubic metres of air per hour were needed from the compressor. The air used was at a pressure of 2—3 atmospheres, whilst steam was employed at 5—7 atmospheres pressure. In the case of burners using steam, boilers of sufficient capacity to supply the steam coils at the same time were installed, and these were heated by waste gas from the furnace. In general, air-pressure burners were preferable to steam-blown burners. A. C.

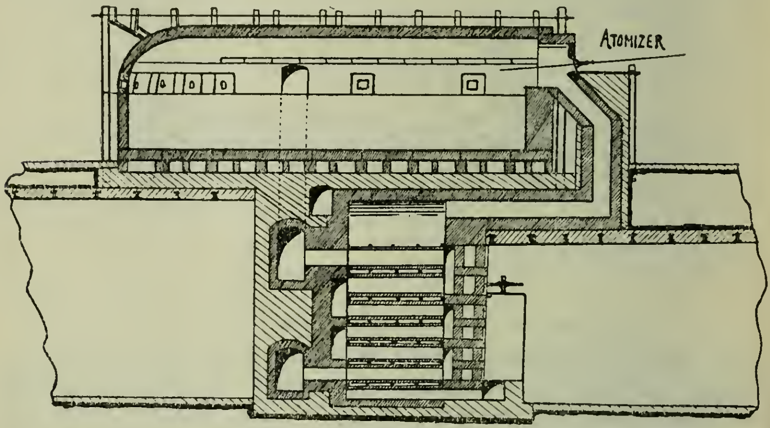

FIG. 136.

228. The Use of Powdered Lignite for Firing Large-sized Furnaces. G. KEPPELER (*Sprechsaal*, 1922, **55**, 80).—The use of powdered peat and lignite for firing was simplified, since these, in consequence of their high oxygen content and low ignition temperature, required less grinding and drying. The powder, atomised by air in a manner similar to that used for oil firing, could be employed to heat furnaces of large size. Lignite drying had been carried on for ten years in the briquetting process. If the powder was needed in fairly large amounts for direct firing, it was possible to make drying independent of briquetting. Steam drying resulted in loss, but the use of furnace gases for this purpose, in consequence of the low ignition point of the material and resulting dust explosions, had been forbidden. The problem of using furnace gases with safety had been solved, however, by Weiss and Häring ("Braunkohle," 1922, **40**, 626). By their method hot gas from a step-grate furnace was passed through an inclined rotary drum, into which the lignite, broken into pieces the size of the fist, was also fed. Gas and lignite so passed in continuous streams along the drying apparatus, the lignite being at a temperature of 50—52°, along the first third of the drum, and leaving it at 60—64°. An exhaust sucked out the gases from the drum at a temperature of 90—100°, so preventing overheating of the dust, which was the cause of the explosions. A wind screen and a centrifugal separator served to remove the bulk of the dust, the remainder of which separated out in a chamber (this, however, in the experimental apparatus, was still faulty and gave a loss of 20 per cent. of the dried coal).

The apparatus dried 31·5 t. of material with a moisture content of 50·5 per cent. and a calorific value of 2250 to a product containing 18·1 per cent. of moisture, per twenty-four hours. The amount of dry coal produced was 15·2 t. with a calorific value of 5590. After being dried, the lignite was ground to powder in a Kent mill, and obtained finally a temperature of 20—25°. For drying, 19·66 per cent. of the material was used, but since the drum was provided with no heat insulation, this could be reduced. The power required for the drying apparatus was 16 h.p. and for the mill 19 h.p. A sample of deposited dust taken from the chamber at 50° did not increase in temperature during a period of observation of fourteen days, whilst the lignite itself in drying showed no sign of decomposition. A furnace heating cast iron blocks and requiring the same high temperatures as glass furnaces had been successfully heated by lignite powder with a saving of 60 per cent. of the fuel in comparison with producer-firing employing lignite briquettes. The material was stated to be capable of use for closed pot furnaces, whilst its suitability for open pot furnaces and tanks was yet an open question. In this respect, it was of interest to note that producers fired with raw lignite, even with a quick draught, did not produce impurities in the glass if a low-ash fuel (2—3 per cent.) was employed and the flame suitably directed. A. C.

229. The Utilisation of the Waste Heat and the Heat Radiated from Glass Furnaces. (*Sprechsaal*, 1921, **40**, 471).—The extent to which waste heat could be utilised depended to a great extent on the individual circumstances of the furnace itself and its situation.

(*a*) *The waste furnace gases.*—Whether the furnace were semi-gas-fired or gas-fired, with recuperation or regeneration, it was generally possible to utilise the waste heat to some extent. Care had to be exercised that the attempt did not impair the actual working of the furnace. Given a furnace with a good chimney draught and a flue from furnace to chimney about 15 metres long, the waste heat could readily be utilised for heating rooms at a distance from the furnace by means of hot water heating. A design suitable for the purpose was described and diagrams were given.

A system of heating coils connected with a collecting boiler was placed in the main flue leading directly from furnace to chimney, due regard being paid to the necessity of leaving sufficient clearance to avoid checking the draught unduly. (A larger flue than customary might be required. Thus a flue that was adequate at 60 × 60 cm. when clear should be enlarged to 80 × 80 cm. when supplied with the heating apparatus.)

The extended surface of the heating coils served to collect a lot of the waste heat and the collecting boiler served as the source of hot water supply to the general heating apparatus. A parallel subsidiary flue from furnace to chimney was provided. This could be shut off wholly or partly by dampers (as also the direct flue containing the heating coils), so that the heating apparatus could be utilised or not as desired.

When the natural chimney draught was not sufficiently good to warrant this system, the heat from the flues could be utilised directly to heat rooms in the immediate vicinity or as the source of heat for sand dryers. In the latter instance, the flues should be covered with cast-iron plates and the sand dried in sheet-iron boxes placed on these plates. The sand should not be placed directly on the covering plates, as in time the dry sand would gradually find its way through interstices in the plates and block the flues.

(*b*) *Radiated heat from the under furnace.*—The author contended that no attempt should be made to utilise heat from the under side of the furnace, since such heat was required in the furnace itself and attempts at economy should be confined to reducing the heat radiated as far as possible by efficient insulation.

(*c*) *Radiation from the melting furnace.*—The only radiant heat that could be utilised efficiently was that from the crown of the furnace and from the working holes. This heat could be utilised readily for heating rooms by having the furnace crown covered by a hood of sheet iron about 20 cm. above the crown and extended down the sides of the furnace as far as possible without being a hindrance to the glassworkers. Better still, the hood could be extended down the sides of the furnace and suitable openings made at the working holes which could be closed by shutters when not required. Hinged doors might be introduced to allow for pot-setting. This hood terminated in a chimney at the top of the crown and from this vertical chimney, which could be closed by a damper, a horizontal flue passed through which the hot air could be conducted as desired by heating pipes and eventually to a chimney stack. When the heating pipes were not required, the hot gases escaped into the air directly through the vertical chimney.

In addition to the economy of heat, such an arrangement improved the working conditions for the glass-makers. J. H. D.

230. In what Manner may the Waste Heat of a Glass Melting Furnace most Suitably be made Useful? M. von Reiboldt (*Sprechsaal*, 1922, **55**, 60).—Various suggestions were made by the author for the utilisation of waste heat. Thus it was possible to build into the chimney flue an apparatus for heating air, or a tube system for heating water, but these, not without reason, were generally held to be a hindrance to the working of the furnaces. Another suggested use for waste heat was for direct heating or drying purposes, by taking the flue through the room to be heated, or building drying chambers over it. These methods only allowed of the retention of a small amount of heat, since, on practical grounds, the chimney was built as near as possible to the furnace, so limiting the length of the flue. The difficulty was overcome by depriving the chimney of one of its functions, that of regulating the draught. This was accomplished by installing a fan with cooled bearings which drove the waste gas into a smoke-box. In the regenerative system the smoke-box and fan were fixed at the junction of the flues carrying the waste gas from the gas and air reversal valves. When the recuperative system was employed the smoke-box was placed immediately adjoining the recuperators. With such an installation the hot waste gas was available for heating pot-, batch-, and mould-rooms, etc. The one disadvantage was that boilers heated by waste gas were liable to be attacked by acid vapours. A. C.

231. Comparison of the Standard Gas Furnace and the Micropyrometer Methods for Determining the Fusibility of Coal Ash. A. C. Fieldner, W. A. Selvig, and W. L. Parker (*J. Ind. Eng. Chem.*, 1922, **14**, 695).—In order to obtain data on comparative results by the micropyrometer, and the standard gas furnace methods, fusion tests were made on a series of coal ashes of varying fusibility. The softening temperature, depending on a number of variables, was used, as empirically defined by the American Society for Testing Materials, being that temperature at which a triangular pyramid 0·75 in. high, and 0·25 in. side of base, mounted vertically, fused down to a spherical lump when heated in the reducing atmosphere of a gas furnace under definitely prescribed conditions. Details of the working methods were given. The results showed that, when fused in a reducing atmosphere of combustion gases, similar to that employed in the gas furnace, some coal ashes gave widely divergent results by the two methods, but those ashes with softening temperatures below 2600° F., by the gas furnace method, agreed to within 100° F. The micropyrometer method gave considerably lower results than the other method for very refractory ashes, but these were not commonly met with.

In the micropyrometer method, a point was reached when the particles coalesced, this point approximating closely to the " down point " of the cones in the gas furnace method for ashes softening up to 2600° F. With refractory ashes, forming viscous slags with longer softening intervals, the " down point " might be from 100° to 500° F. higher than in the other method. With reducing atmosphere, the micropyrometer method was quicker, and more convenient. The results were checked by different operators, and agreed as closely as those obtained with the gas furnace. The methods could not be regarded as alternative for all types of ashes.

V. D.

232. An Electrical Method of Freeing Producer Gas from Dust. (*Sprechsaal*, 1922, **55**, 145).—Solid impurities in producer gas consisted mostly of fragments of ash, of powdered fuel, and of soot obtained by decomposition. The amount produced was dependent on the type of fuel, on its moisture content, the gas pressure, and the charge in the producer. Estimations indicated 2—18 gm. per cubic metre of gas (at 0° and 760 mm. pressure). With lignite, which gave 3 cubic metres of gas per kilogram, a dust content of 10 gm. per cubic metre of gas was found. Thus a producer consuming 20 tons * per twenty-four hours gave $\frac{20,000 \times 3 \times 10}{1000} = 600$ kg. of dust in this period. This dust interfered with working by choking up the flues, and also caused impurities in the glass. The usual method of removing it consisted in installing dust-chambers or bent flues. Fig. 137 indicated the construction necessitated where relatively high gas pressures were used, and when the dust was of very low density, as was the case when lignite or peat was employed. Recently an electrical method, that of Cottrell and Möller, had been successfully used in many works for removing dust from the gas. By it, the gas was passed through a high tension electrical field in which a current passed from wires placed either axially along pipes (Fig. 138), or between metal plates. The current, streaming from the wires to the tubes or plates, carried with it the dust, which then fell into a chamber below and was from time to time removed. A direct current was employed, working intermittently, and this was obtained by transforming an alternating current, transformation and interruption being produced by a rotating disk with metal segments. Only a small current density (a few milliamperes) was necessary, whilst the power required was only a few kilowatts. This apparatus removed 99 per cent. of the dust from producer gas and could be run by rational use of waste heat which was found in the glass factory. A. C.

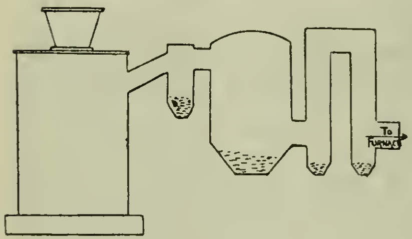

Fig. 137.

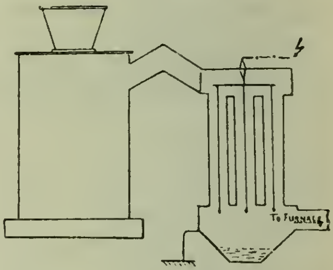

Fig. 138.

233. The Smoke Nuisance in the Glass Industry. L. Springer (*Glashütte*, 1921, **51**, 355, 371, 387, 403).—The troublesome constituents of waste gases were soot, tar products, and acid gases. Soot and tarry derivatives indicated wrong furnace conditions, such as a furnace too cold or a lack of air. They could be obviated, except in heating up the furnace or during reversal, by careful regulation. Although unpleasant, such fumes were not harmful to life. Acid gases, chiefly sulphur dioxide and hydrofluoric acid, were more harmful to plants than to animal life. Sulphur dioxide was obtained in gas from lignite and coal fuels, which contained sulphur compounds (as pyrites), but not from wood, peat, or coke. Salt-cake also, when used as a batch material, resulted in the liberation of sulphur dioxide, as did materials such as sulphur or cadmium sulphate, used for the production of amber glass. Finally, hydrofluoric acid was obtained from such batch materials as fluorspar, cryolite, and sodium silicofluoride, whilst hydrochloric acid was liberated when an alkali containing chlorides was employed. In England, the Alkali Acts of 1863 and 1881 prohibited a higher sulphur content in waste gases than that equivalent to about 9 gram SO_2 per cubic metre (=0·24 per cent. by volume), and a hydrochloric acid content of about 0·5 gm. per cubic metre. In Prussia an order in 1895 for sulphate factories stated that high chimneys should be built, and that the gas should be so diluted that the sulphur content of the air in the neighbourhood of dwellings should not exceed 0·8 gm. of SO_3 per cubic metre (=0·02 per cent. by volume), whilst in Prussia and Saxony in 1912, the limit of the sulphur content of waste gases (where concessions for new plants were granted) was placed at 5 gm. of SO_3 per cubic metre. Sulphur fumes emitted from fuel were dependent on the volatile and not on the total sulphur content of the fuel. Thus coal with 1 per cent. volatile sulphur, using twice the air theoretically necessary, as in the case of direct firing, would give a waste gas with 0·04 per cent. by volume of SO_2 (1·5 gm. of SO_3 per c.m.). Such an amount would not be seriously inconvenient unless emitted in large quantities or from a low chimney or in hilly country. On the other hand, an ultramarine factory, using fuel emitting smoke containing an average of 0·3 per cent. by volume of SO_2, proved very troublesome, as did a factory using coal with an average of 3·5 per cent (2 to 8 per cent.) of volatile sulphur and giving smoke containing 0·024 to 0·18 volume per cent. of SO_2. Dralle stated that with a glass batch of 100 parts sand, 40 limestone, 40 salt-cake, 2 coal (neglecting the effect of the fuel), the waste gases would contain 0·4 per cent. by volume of SO_2, whilst Wislicenus, by direct measurement, found a value of 0·44 per cent. The figure was calculated in order to show that, owing to the great dilution of the gas, conversion to sulphur or sulphuric acid was impossible. A further factor to be remembered was that acid gases from batch materials were only evolved during the actual period of melting. Hydrofluoric acid was more troublesome than sulphur dioxide, since when emitted, it settled to the ground. On the other hand, it was never formed in very large quantities, and Haselhoff and Lindau had only found a single case of destruction of vegetation which might be put down to this cause. To decide whether decay of vegetation was due to sulphur fumes or not, recourse was made to an analysis of the sulphur content of the ash of fresh and of dead foliage. Thus, in one case, sound pine needles gave an ash of 2·65 per cent. with 0·20 per cent. of SO_3, those attacked by acid fumes an ash of 3·02 per cent. with 0·35 per cent. of SO_3. A. C.

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* Metric ton.

234. Specific Heat of Gases from the Point of View of their Industrial Applications. E. DAMOUR and D. WOLKOWITSCH (*Revue de Métallurgie, Memoires*, 1922, **19**, 145).—An examination and discussion of the various determinations made up to date of the specific heats of gases. The authors concluded that the best results were still those of Mallard and Le Chatelier.

W. E. S. T.

235. The Estimation of Apparent Porosity of Ceramic Materials. O. KALLAUNER, R. BARTA, and J. SIMANE (*Sprechsaal*, 1922, **55**, 45, 58).—A comparison of the results obtained by the use of the previously published methods of other workers. Test pieces were made of pressed clay slabs of size 8·35×4·00×1·90 cm., and burnt at Seger cones 010, 1, and 6, respectively, whilst in addition pieces of various sizes cut from bricks, firebricks, and earthenware plates were taken from selected manufacturers. In general, after each experiment the slabs were dried at 110°, and before re-using were again weighed. At normal pressures, the tests were performed in flat porcelain dishes, whilst Fig. 139 illustrates the apparatus used for work at reduced pressure. Qualitative results by Bischof's method, that is, by noting the time taken by a water-drop of 0·5 c.c. size to sink into the surface, gave the values :—

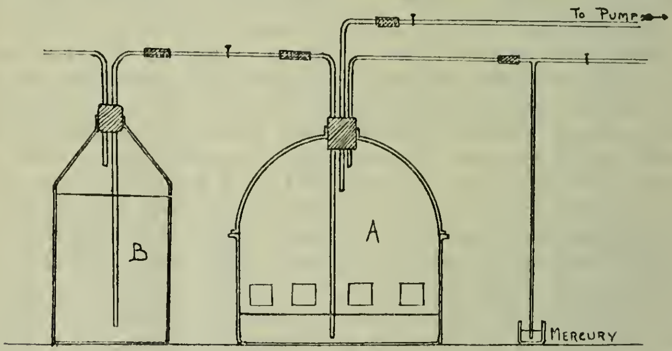

FIG. 139.

Temp. of burning.	Time taken. mins.	secs.	
S.K. 010	3	30	mean of ten determinations
1	2	30	
6	no penetration		

The following Table I gives a list of the quantitative results obtained by use of the methods due to the individual workers named.

TABLE I.

Method.	Apparent porosity at Seger cone : 010	1	6
(*a*) Saturation at normal temperature and pressure :			
(1) Seger (150 hours)	14·61	5·18	1·56
(2) Hatt and Schofield	14·50	5·07	1·00
(3) Binns	14·23	5·02	0·90
(4) Leduc	15·82	5·52	1·95
(5) Munich Conference method (1884)	14·69	5·96	2·12
(6) Austrian "Tonindustrie-Zeitung"	16·05	5·96	2·12
(*b*) Saturation at ordinary pressures with boiling :			
(1) Plenske	13·70	5·50	0·45
(2) Hoffmann	13·75	5·61	0·45
(3) Aron	13·81	5·61	0·45
(4) Dümmler	14·47	6·49	1·59
(*c*) Saturation at lower pressure and normal temperature :			
(1) Bauschinger (twenty-four hours)	16·00	8·55	2·40
(2) Leduc	16·24	9·28	2·59
(3) Rieke	15·11	5·77	2·38
(*d*) Saturation at lower pressure with boiling :			
(1) Buckley 1898	16·18	9·04	3·66
(2) Buckley 1904	15·95	8·37	3·03
(*e*) Saturation at higher pressure :			
(3 atmospheres, twenty-four hours)	15·52	6·94	1·99

Table II contains the values of apparent porosity (p_z) calculated from observations made of the real porosity (p_s) by the use of equation $p_z=\frac{p_s}{o}$, where *o* was the volume-weight of the material. The experimental values most nearly approaching the calculated values were *c*, *d*, 1, and 2 for those samples burnt at Seger cone 010 and 1.

TABLE II.

Condition.	Shrinkage per cent.	Volume-weight.	Specific weight.	Porosity per cent.	
				real	apparent (calc.)
Dried at 120°	10·8	—			
S.K. 010	0·5	1·85	2·64	29·93	16·18
S.K. 1	3·8	2·05	2·60	21·11	10·30
S.K. 6	5·8	2·25	2·57	12·46	5·53

In general, the value of the apparent porosity was increased by abstracting air from the test-piece and by increasing the solubility of the air in the water. These were obtained by long contact of the material with water (most suitably boiled), and further by boiling in water and afterwards cooling, or by reduction of the pressure. In saturating, it was necessary to admit the water gradually to the material, so that the water level was only up to the height in which it had risen in the pores due to capillarity. Values obtained by the use of portions of the test-pieces were of importance, since in these cases surfaces were used which had not been directly fired. When material was used which dissolved appreciably in water, it was found necessary to allow for the dissolved matter, and this was done by drying at 110° and re-weighing. The following rules were laid down with regard to the preparation of samples for testing for apparent porosity: (*a*) From bricks: a piece of 6 cm. diameter and of a height corresponding with the thickness of the brick should be cut from its centre. (*b*) From large objects: if not homogeneous, samples of 100 c.c. volume should be taken, since inhomogeneity of the material might give inaccurate values if smaller portions were used. Samples should be as nearly cylindrical or cubical as possible. In preparing the test-piece all powder should be removed from the surface by means of bellows or a fine brush. The material should be dried at 110°, cooled, and weighed to within at least 0·1 gm. According to the authors, the best method of saturating with water at normal pressure was by laying the test-pieces, not in contact with one another, on a grid made from glass rod in a flat dish. Boiled (air free) distilled water was then poured gradually into the dish until the material was, by its capillarity, saturated with water. The addition of water was continued until the level was 1 cm. above the test-piece, after which it was boiled for an hour, the level being maintained by addition of boiled distilled water. The dish and contents were rapidly cooled and left to stand for twenty-four hours. On removing the slab from the water, its surface was wiped with a sponge (previously moistened and wrung out) and it was then weighed. When lower pressures were used the slabs were placed in the vessel *A*, which was then exhausted for half an hour by means of a good water-pump, after which boiled out, rapidly cooled, distilled water was slowly introduced from the vessel *B* until the lever was 1 cm. above the top of the slabs. The apparatus was left twenty-four hours under a pressure of about 16 mm. of mercury (more porous materials could be removed from the water after five minutes). Finally, the slabs were removed, the surfaces wiped as before with a sponge, and the test-pieces weighed. A. C.

236. Characterisation of Clay. N. H. Comber (*J. Soc. Chem. Ind.*, 1922, **41**, 77 T).—After quoting evidence for the view that all clays have a colloidal emulsoid surface, the author attributed the difference between "fat" and "lean" clays to the higher proportion of emulsoid surface to a suspensoid core in the fat clays. This view was essentially in agreement with that of Rohland, who obtained a relative measure of the ratio by estimating the water required to bring the clay to the optimum working condition, arguing that the "fat" clays imbibed the most. The author approached the problem from the point of view that the "fatter" the clay, the more voluminous the coagulum with calcium hydroxide. As, however, a clay even when shaken up with water still remained aggregated to a large extent, the addition of the hydroxide would not produce a reaction with the maximum surface.

The addition of an alkali, such as ammonia, first, would peptise the solution and if a calcium salt then be added, the reaction would involve the maximum surface.

Four clays were tested as follows: Two half-gram samples of the clay were placed in similar test-tubes, 10 c.c. of water added to each and the tubes inverted several times. To one of the tubes two drops of a standard ammonia solution were added and the contents mixed. Five minutes afterwards, 1 c.c. of $N/10$-calcium nitrate was added to each tube and the contents were again mixed. Flocculation was more rapid in the alkaline suspension. Sedimentation was allowed to proceed to completion and the volumes of the coagula compared. With a Farnley fireclay and a bauxitic Ayrshire clay, both lean, there was little notable difference in the volumes. With a fat Dorset ball clay the alkaline coagulum was about 50 per cent. greater than with the neutral. With very fat Halifax clay, purified by electro-osmosis, the alkaline coagulum was 150—200 per cent. greater than the neutral. M. P.

237. Resistance Tests on Firebricks under Load at High Temperatures. E. Sieurin, F. Carlsson, and B. Kjellgren (*J. Amer. Cer. Soc.*, 1922, **5**, 170).—The authors attempted to determine the influence of variations in chemical composition on the resistance of clays under load at high temperatures.

A primary mass of clay was prepared by mixing equal parts of blue clay and washed China clay. This mixture was wet-ground so as to pass a screen of 10,000 meshes to the square centimetre. Grog, made from the mixture, was burnt at 1410° and then ground to two sizes, one lying between 4 and 20 meshes per linear inch and the other finer than 7-mesh. Samples of mixed clay with grog were made into the form of 30 mm. cubes and burnt at various temperatures for test. For comparison with this primary or standard batch, samples were similarly prepared from definite mixtures of silica, alumina, ferric oxide, lime, and magnesia.

Fusion points and "softening temperatures" were determined. The latter might be defined as "the temperature at which the test-cube, subjected during two hours to a load of 2 kilograms per sq. cm., experienced a linear contraction of 0·3 per cent. of the original length."

Heating took place in an electric, carbon-resistance furnace with carborundum tubes. The test pieces, in the centre of the furnace, rested on the end of a carborundum rod, and pressure was applied by means of a loaded, second rod of carborundum. In order to determine the softening temperature of a test mixture, a series of pressure tests was carried out, first at high temperatures and then at lower temperatures, until finally the cube was no longer compressed. The softening temperature of the original mixture was found to lie between cones 9 and 10, as indicated by the following results:

Cone	11	11	10	10	9	9	8	8
Percentage contraction at the end of two hours	2·9	3·2	0·9	1·2	0·3	0·2	0·0	0·0

The fusion temperature was cone 34 (1750°) when the percentage chemical composition was as follows :

SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	Total.
54·52	43·04	0·89	0·68	traces	0·78	0·0	99·91

Silica was added in the form of quartz with a silica content of about 99 per cent. A definite minimum for the softening temperature was found to exist when the silica content was between 60 and 70 per cent. This was considerably below that for the fusion point, for which the minimum was round about 90 per cent. silica. The coarser grained mass (grog 4- to 20-mesh) gave a considerably lower softening temperature than the finer grained mass (grog below 7-mesh), due to the presence of certain hollows which caused a more rapid contraction.

Alumina was added in the form of chemically pure, calcined alumina. With increasing percentage of alumina, the softening temperature gradually and continuously increased. A sudden fall in the softening temperature, occurring at about 80 per cent. of alumina, was probably due to the fact that the small quantity of bind clay was insufficient to keep the alumina grains together and was not a real softening temperature. The finer grained mixture again showed a considerably higher softening temperature than the coarser grained.

Chemically pure ferric oxide, added in amount sufficient to increase the percentage by 0·64, produced a lowering of the softening temperature of 50°. After this point, the softening temperature declined more slowly, and was almost constant for mixtures containing between 6 and 12 per cent. of ferric oxide, thereafter falling more rapidly. The difference between the two grain sizes of the mixture was only slight when ferric oxide was added.

A slight increase of lime content (produced by addition of pure, precipitated chalk) considerably reduced the softening temperature. With further increase, the softening temperature fell less rapidly. Investigations were being made to ascertain the softening temperature with a lime content lower than the 0·68 per cent. in the original mixture, since it was anticipated that it would result in a higher softening temperature.

Magnesia acted similarly to lime, but to an even greater degree, an increase of magnesia content from 0·0 to 0·08 per cent. causing a fall of softening temperature from 1280° to 1240°. The finer grained mixture had the higher softening temperature when lime or magnesia was added.

Full tables of details and curves were given. F. W. H.

238. The Testing of Silica Brick. K. H. Endell (*J. Amer. Cer. Soc.*, 1922, **5**, 209).—The properties tested were specific gravity, temperature of rupture, and softening temperature under a load of 1 kilo. per sq. cm., the linear expansion after repeated heating to a temperature of 1600° and the microstructure (principally the proportion of *quartz* to *cristobalite* and *tridymite*). Chemical analysis, the temperature of fusion, the porosity, and mechanical strength when cold were not considered of great importance.

The specific gravity was determined on finely powdered material in small pycnometers of 3 c.c. capacity. The load test was made by means of an apparatus in which pressure was applied to small test cylinders 50 mm. in diameter and the same in height, by means of a hollow carborundum rod. The rod and the test piece were enclosed in a granular-carbon resistance furnace, the temperature of which was read by means of an optical pyrometer sighted through the hollow pressure rod. The volume changes were indicated by a pointer and scale and recorded by means of a revolving drum. The linear expansion was determined by direct measurement, using a sliding gauge, before heating and after cooling. Test cylinders of the size previously indicated and with the ends ground and polished were heated in granular-carbon resistance furnaces for about an hour and a half up to a temperature of 1600°, maintained at that temperature for half an hour, and then allowed to cool. In the examination of the microstructure of the bricks, it appeared sufficient to determine, from photomicrographs, the amount of *quartz* and of silicates, the grains of which had a higher birefringence and a higher index of refraction. This was done by placing a "grating" of transparent paper, ruled in 1 mm. squares, on the photomicrographs, which were usually magnified one hundred times. The squares containing *quartz* and silicate crystals were pricked with a needle and counted. The remainder covered *cristobalite* usually, whilst *tridymite*, in finished silica brick, was represented in most cases by less than 5 per cent. The *tridymite* was estimated and the *cristobalite* determined by difference. The author considered this method to be accurate to about 2 per cent.

Samples of American, German, English, and Swedish silica bricks were submitted to the above tests. A selection from the results is given below.

				Microstructure. Contents per cent.		
	Specific gravity.	Softening temperature under load.	Linear expansion, per cent.	Quartz plus silicates.	Cristobalite.	Tridymite.
German bricks :						
Basic steel type ...	2·42	1520°	3·2	16	82	2
Coke-oven type ...	2·49	1470	4·5	30	70	—
Glass-furnace type	2·47	1600 *	4·0	40	60	—
American bricks :						
Medina quartzite...	2·34	1535	0·5	14	81	5
Baraboo quartzite	2·33	—	—	13	82	5
English bricks :						
Ganister	2·40	1670	4·0	19	76	<5
Swedish bricks :						
Quartzite	2·34	1650 *	1·7	15	80	<5

The author suggested the following specifications for good silica bricks : a true specific gravity not greater than 2·38, a permanent linear expansion, under the conditions specified, not greater than 2 per cent., and a quartz and silicate content not greater than 15 per cent.

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* Temperature of rupture.

F. A. Harvey and E. N. McGee stated, in discussion, that they themselves determined the apparent specific gravity. This was done by boiling samples for an hour and a half under a vacuum of at least 20 inches of mercury and the values obtained were about 0·02 lower than the true specific gravity determined by Endell. In their determinations of expansion, they heated samples very slowly to 1450° and maintained them at that temperature for seventy-two hours. They doubted whether Endell's rate of heating to 1600° was slow enough to give consistent results. The hot crushing strength, as determined on American bricks by the method C 16—20 of the American Society for Testing Materials, gave considerably higher results than those of Endell for German and American silica bricks. F. W. H.

239. The Influence of Grinding and Burning on the Characteristics of Silica Brick. R. M. Howe and W. R. Kerr (*J. Amer. Cer. Soc.*, 1922, **5**, 164).—Sample bricks of the same batch composition were made from silica mud after grinding for ten, fifteen, and twenty minutes, respectively, and sets made from the several sizes of grain were burned at each of six temperatures, ranging from cone 11 to cone 19.

The increase in the time of grinding reduced the amount of material remaining on a 10-mesh sieve from 17·8 per cent. after ten minutes, to 10 per cent. after fifteen minutes, and 3 per cent. after twenty minutes. The portion passing through a 140-mesh sieve was correspondingly increased from 27 per cent. after ten minutes, to 28·1 per cent. after fifteen minutes, and 34·1 per cent. after twenty minutes. Finer grinding improved the appearance of the bricks and increased their strength somewhat, but not in any marked degree within the commercial limits of grinding. Average figures for several properties at all six temperatures were given as follows :

Time of Grinding. Minutes.	Specific gravity.	Residual Permanent Expansion (percentage).	Modulus of Rupture, lb. per sq. inch.	Porosity (percentage).
10	2·362	1·5	440	26·86
15	2·368	1·6	446	27·76
20	2·365	1·6	499	28·71

A grinding of from fifteen to twenty minutes appeared to be of most advantage.

The firing temperature was the principal factor governing the final strength and also the permanent residual expansion. The bricks fired at the maximum temperature tried, namely cone 19, possessed the highest strength and the lowest expansion. The influence of the firing temperature on several characteristics of silica bricks was demonstrated by the following figures as the average values for the three grain sizes at each cone :

Firing temperature (Cones).	Specific gravity.	Residual permanent expansion (percentage).	Modulus of rupture (lb. per sq. inch.).	Porosity (percentage.)
11°	2·50	4·2	303	27·91
14—15	2·38	2·0	358	28·30
16—17	2·35	1·3	444	28·05
17	2·33	0·8	572	28·08
18	2·31	0·4	533	26·72
19	2·30	0·2	614	27·59

F. W. H.

240. A Simplified Method of Determining the Dry Volume of Clay Briquettes. J. L. Crawford (*J. Amer. Cer. Soc.*, 1922, **5**, 394).—Four or five briquettes were weighed dry and then saturated with kerosene. Their volumes were determined in the usual manner and the "bulk specific gravities" (specific gravity of the composite piece) by means of formula (1) or (2):

$$\text{Bulk specific gravity} = \frac{\text{Dry weight}}{\text{Volume}} \text{ (by volumeter)} \quad . \quad . \quad . \quad (1)$$

$$\text{Bulk specific gravity} = \frac{\text{Dry weight} \times \text{specific gravity of kerosene}}{\text{Saturated weight} - \text{suspended weight}} \text{ (by weighing)} \quad . \quad (2)$$

All other test pieces could be weighed dry and their volumes determined by formula (3) namely,

$$\text{Volume} = \frac{\text{Dry weight}}{\text{Bulk specific gravity}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

By using this method, equally as correct as the standard method of the American Ceramic Society, it was unnecessary to saturate any of the briquettes with kerosene. This reduced the number of weighings, eliminated the difficult task of drying oil-saturated pieces, prevented cracking in the furnace, and gave a smooth burning curve when determining volume firing shrinkages.

F. W. H.

241. The Reversible Thermal Expansion of Silica. H. S. Houldsworth and J. W. Cobb (*Trans. Cer. Soc.*, 1922, **21**, 227).—In the present paper, the reversible linear expansions of the various forms of silica are dealt with, the results being usually stated in two forms, the one embodying a description of dimensional alterations, the other of crystallographic structure, the latter being checked by determinations of specific gravity and refractive index.

The apparatus used in the firing of the test pieces, together with the mode of operation, have been described previously (see this Journal, 1919, **3**, T., 201), as also the method of determining porosity (*ibid.*, 1921, **5**, 35).

(*a*) *Pure Amorphous Silica* (prepared from silicon fluoride).—Pure amorphous silica was studied as being devoid of the definite orientation of the crystalline forms it might pass through. Test pieces were made by binding the silica with gelatin, not more than 0·18 per cent. of impurity (ash) being introduced thereby. The pieces, after being heated at 700° in a muffle, showed no expansion or contraction on re-heating (that is, there was no indication of any transformation to the crystalline forms).

After being fired to 1170° and reheated, the following changes were observed :

15—150°, large rate of expansion.

150—240°, extremely large expansion, characteristic of the change α—β-*cristobalite.*

240—500°, slight expansion.

500—650°, very little change.

650—1000°, slight contraction.

Microscopic examination showed the conversion of the silica to *cristobalite.*

(*b*) *Precipitated Silica containing Soda* (about 5 per cent.).—After heating in a muffle at 700° and then reheating over various temperature intervals, the results observed were :

15—170°, slight expansion.

170—210°, a large, rapid, and reversible expansion was noted (α—β-*cristobalite*).

210—420°, a steady expansion.

420—700°, a contraction.

The silica was readily and largely converted to *cristobalite.*

If the test piece was maintained at 700° for two hours, cooled, and then reheated, the observations showed that more *cristobalite* was formed than during the first heating.

The same silica was then reheated to 1170°, cooled, and on again reheating gave, for different temperature ranges :

15—100°, a steady expansion.

100—200°, an increased expansion (five times as great as that up to 100°).

200—250°, decreased rate of expansion.

250—550°, expansion nearly the same as from 15—100°.

550°, the expansion ceased abruptly and there was a slight contraction up to 1000°.

On cooling, the more rapid expansion between 100° and 200° was reversible. The data suggested that *tridymite* was present in quantity. The presence of the soda was apparently responsible for the formation of *cristobalite* at a lower temperature and for the formation of *tridymite.*

(*c*) *Silica Glass* (*Vitreosil*).—Experiments showed that little change took place in vitreosil tubes by repeated heatings to 1000° or by four hours' burning at 1150—1170°. After firing for three hours to cone 14, some *tridymite* appeared, whilst heating for two and a half hours at 1510—1555° resulted in from 30 to 50 per cent. of the vitreosil being transformed into *tridymite.*

Almost all naturally occurring silica deposits were quartzitic, and yet quartz was not obtained from amorphous silica in any of the above experiments. Probably the natural deposits were formed under great pressure.

(*d*) *Meanwood Ganister without Bond.*

First time heating:
15—500°, large expansion.
500—600°, still greater expansion (α—β-quartz).
600—900°, small expansion.
900—1000°, slight contraction.
On cooling:
1000—600°, slight expansion.
600—550°, very rapid and large contraction (β-quartz—α-quartz).
550—15°, steady contraction.

On reheating, the character of the temperature-expansion graph was the same between 15° and 600° as that for the first heating, although the actual expansion was only about two-thirds of that previously observed. Between 600° and 1000° there was a slight, steady contraction.

The cooling curve did not differ appreciably from the heating curve, but from 400° to 15° the contraction was less than the expansion, showing a further permanent linear expansion. Specimens of Meanwood ganister without bond were also heated repeatedly to cone 9 and subsequently heated to cone 14. This converted a small part of the *quartz* into *cristobalite* (no *tridymite*).

On firing to cone 20, the whole of the *quartz* was changed; *cristobalite* was in large excess of the *tridymite* produced.

(*e*) *Meanwood Ganister with a Lime Bond.*—Meanwood ganister was ground, sieved through a 25-mesh standard sieve, mixed with 3 per cent. plaster of Paris added as slip, moulded, and dried.

Test pieces showed the large *quartz* (α—β-conversion) expansion between 500° and 600°.

No *cristobalite* was detected after a works firing to cone 9.

Examination after a subsequent firing to cone 15 showed that the specimen was a mixture of *quartz* and *cristobalite* with *quartz* in excess.

Examination after another firing at cone 19 for two hours indicated that more *cristobalite* was formed, but *quartz* was still present. The difference in behaviour of the ganister with and without bond would suggest that the bond material was responsible for the delay in the formation of the *cristobalite* crystals.

(*f*) *Quartzite.*—A Welsh quartzite (Biolchgwyn) was selected.

Quartzite with a lime bond showed a little *cristobalite* in the *quartz* after a works firing at cone 9. There was more *cristobalite* at cone 14, and still more at cone 20. This showed that quartzite was transformed more easily than ganister.

(*g*) *Flint.*—Flint with a lime bond was transformed even more easily than quartzite. Ganister, quartzite, and flint all underwent a considerable permanent linear expansion in the lower temperature ranges before any conversion of *quartz* occurred. The true specific gravity and refractive index were not altered thereby, but the porosity increased.

None of these three raw materials gave *tridymite* in any quantity.

(*h*) *Silica Bricks.*

(1) Manufactured from Welsh quartzite:

15—250°, a very large expansion.
250—550°, a smaller but regular expansion.
550—600°, an increased expansion.
600—750°, a small expansion.
750—1000°, a slight contraction.

The large expansion up to 250° could be associated with the transformations of much *cristobalite,* whilst the increased rate of expansion from 550° to 600° would correspond with the change α—β-*quartz.*

Owing to the large expansion accompanying the *cristobalite* inversion, the expansion of the brick from 15° to 1000° was more than double that of a fireclay brick.

(2) Manufactured from Yorkshire quartzitic pebbles. This brick showed the α—β-*cristobalite* expansion, but no α—β-*quartz* expansion between 500° and 600°.

A little *tridymite* may have been present.

(*i*) *Silica Bricks* (from Welsh quartzite) *after long use.*

(1) From a coke oven (maximum temperature 1450°). The innermost exposed layer was an impure glass with a steady expansion, but only half as large between 15° and 1000° as that of the layers behind.

The remainder of the brick was all *cristobalite* with very little *quartz* or *tridymite.*

(2) *After use in the roof of a steel furnace* (maximum temperature 1600—1650°). The layer exposed to the furnace heat was practically all *cristobalite* and silicates, the next layer the same; the third layer showed some α—β-*quartz* expansion as well as the α—β-*cristobalite* expansion, whilst the fourth, outermost, layer exposed to air was the same as the brick before use.

The exposure to high temperature had evidently completed the change *quartz* → *cristobalite* which had been largely effected in the kiln during manufacture. Little or no *tridymite* had formed.

In the discussion, this statement concerning the absence of *tridymite* was strongly criticised, as it was asserted that a good deal of *tridymite* had been observed in thin sections cut from bricks used in open-hearth furnaces; also that *cristobalite* and *tridymite* together with much *magnetite* had been developed in the roofs of several steel furnaces. A. M. J.

242. Carborundum. M. F. PETERS (*J. Amer. Cer. Soc*., 1922, **5**, 181).—A study was made of carborundum-clay mixtures with reference to the relation between the proportion and size of the constituents and the properties of the refractory, more especially the tensile strength, the load test, the slagging, and the spalling tests.

The carborundum should contain a maximum amount of coarse material with a minimum of fine, but sufficient of the latter must be added to fill the spaces between the coarser particles.

Whenever two substances were mixed together, one being the inert material and the other the bond, it was necessary (*a*) to cover each particle of inert material with bond, and (*b*) to fill the spaces between those particles. The percentage of clay which should be added to the carborundum to fill the spaces would depend on the ratio of the sizes of the carborundum particles.

Other things being equal, the tensile strength of any mixture of carborundum and clay was proportional to the bonding power of the clay. When different percentages of carborundum and clay were mixed the tensile strength increased rapidly at first, then remained practically constant, and finally decreased very rapidly. The correct percentage of carborundum to use in any mixture to obtain the maximum tensile strength depended on the physical characteristics of the clay.

The linear compression under the load test varied as the second power of the percentage of carborundum present, so that when bricks were to be subjected to great pressures the percentage of carborundum should be as high as possible.

Carborundum would resist the action of most slags better under reducing than under oxidising conditions. It would not resist slags rich in iron, lead, or lime, but would resist those rich in silica. The length of time a brick would resist spalling depended on the percentage of carborundum in the brick, the tensile strength, coefficient of expansion, and thermal conductivity of the clay. Each bond clay presented a different problem and the proportions to use could only be determined by trial.

A formula was derived showing that a good bond clay should have the following properties: (1) high tensile strength, (2) high softening point, (3) low coefficient of expansion, (4) high thermal conductivity; whilst a good body should have (1) rigidity at high temperatures, (2) low coefficient of expansion, and (3) high thermal conductivity.

When refractory materials were to be used in places where the physical destructive forces were great (spalling, compression, abrasion, etc.), and the chemical forces weak, carborundum would make an excellent grog. If slags which came into contact with the refractories were rich in silica, carborundum might still be used, but not when rich in iron, lead, or lime. F. W. H.

243. Tentative Specifications for Glass-house Refractories. (*J. Amer. Cer. Soc.*, 1922, **5**, being Year Book for 1921–22, p. 129.)—The specifications given were intended as a nucleus, to which others were to be added when more data should be available. Briefly, they were as follows:

Glass Melting Pots.—The softening point, determined according to American Ceramic Society specifications, from cones of raw pot clay mixture, shall not be less than that of Seger Orton cone 29, and the softening point of any individual plastic clay constituent not less than cone 27.

Flux Blocks.—The softening point of sample of burned block shall not be less than Seger Orton cone 27½. The porosity shall not exceed 26 per cent.

Clay Refractory Blocks and Bricks.—The subject of load test, reheating test, and softening point were still under consideration.

Silica Refractories.—These should ring well when struck. The specific gravity should not exceed 2·38 for brick made from Medina quartzite, and not more than 2·42 if made from Baraboo quartzite. Silica brick should not contain more than 3 per cent. of CaO, or more than 1·75 per cent. of Al_2O_3. V. D.

244. Heat Transmission with Special Reference to the Stoker Fired Boiler. R. M. Howe and S. M. Phelps (*J. Amer. Cer. Soc.*, 1922, **5**, 420).—It had been noted that the service obtained from the refractory materials was usually shorter when used with low-grade fuel burned by forced draught (automatic stoker). The decreased service was not due to higher furnace temperatures, to increased slag action, or to spalling. It was, however, demonstrated that the temperature within the brickwork depended to a large extent on the pressure within the furnace. Fireclay tiles were made so that temperature readings could be obtained at several distances from the hot surface. These tiles were placed in the door of a furnace, pugged up with fireclay, and heated under the conditions indicated below. The temperature measurements were checked every hour and finally recorded when equilibrium was established. The data obtained were :

Furnace temperature		1340°	1340°	1340°	1220°	1220°	1220°
Pressure of furnace gases (inches of water)		+1·00	+0·05	−0·30	+0·95	+0·05	−0·30
Temperature of firebrick at specified distance from hot surface	0·5 in.	1305°	1265°	1105°	1105°	1075°	900°
	1 in.	1270	1210	1020	1035	965	800
	2 in.	1125	1040	800	900	770	620
	3 in.	1040	950	720	800	660	490
	4 in.	845	745	515	665	510	355

When the gases were under positive pressure they penetrated the brickwork, and raised the temperature of the brick to a point above that which would result from simple thermal conductivity. On the other hand, with negative pressure, cold air was drawn through the brickwork into the furnace and exerted a cooling effect. Spalling was therefore associated with furnace pressure, being greater when the pressure was positive. This was due to the fact that spalling was a function of vitrification which, in turn, was a function of the temperature.

The authors believed that these results might explain the lack of concordance between the results of investigators of thermal conductivity. The latter probably represented heat transmission in a number of cases and therefore were higher or lower than the conductivity according to the direction of the flow of gases. An electrically heated furnace, it was considered, should reduce errors in thermal conductivity measurements to a minimum.

The results also set a limit to the application of the load test. They demonstrated that the fall in temperature was very sudden in uninsulated walls. Consequently, the major portion of a firebrick would be at a sufficiently low temperature to carry the load of the average installation. The load test was, therefore, directly applicable only to muffles and cases when insulation was used.

F. W. H.

245. A New Method of Charging Batch into Tank Furnaces. R. Good, Washington, Pa., Assignor to Hazel Atlas Glass Co., West Virginia (U.S.A Pat., No. **1421210**, June 27th, 1922. Filed December 1st, 1919, No. 341732).—Built into the crown of a tank furnace are a number of refractory blocks with circular apertures, 7, into which are fitted fireclay cones, 8, the weight of which is carried by the shoulder, 9. The lower end of these fusion cones descends an appreciable distance within the furnace, and they terminate in a restricted orifice, 10. The mixed batch is supplied to these cones by gravity through a water-cooled sleeve, 11 and 14, and when in the cone begins to fuse. As fast as it becomes sufficiently fluid, it flows through the small orifice, 10, into the glass already in the tank.

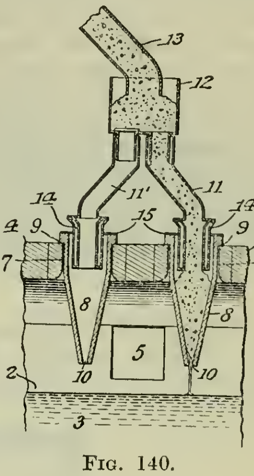


Fig. 140.

It is claimed that with such an arrangement, melting proceeds very economically, since it uses heat which is otherwise practically wasted. Further, the refining process is not periodically checked by the introduction of large quantities of cold batch. The sides of the tank are also saved from the corrosive action of melted batch constituents, the corrosion being effective in the fusion cones, which can very easily and cheaply be replaced when necessary. S. E.

246. An Improved Tank Furnace. G. C. Heilman, Philadelphia, Pa. (U.S.A. Pat., No. **1422858**, July 18th, 1922. Filed October 20th, 1919. No. 331804).—The invention consists of a recuperative tank furnace, shown in longitudinal section in Fig. 141,

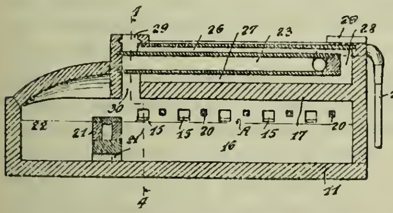


Fig. 141.

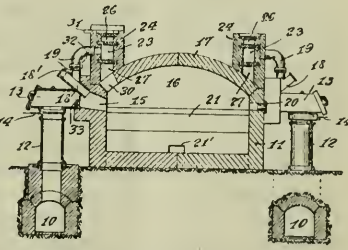


Fig. 142.

and in cross section in Fig. 142. Gas from producers is supplied through two mains, 10, and from these mains, upright pipes, 12, lead to horizontal pipes, 13, the connection being controlled by dampers, 14. The discharge end of each pipe, 13, connects with a mixing and combustion chamber, 15, which is contracted towards its outlet, where it discharges into the tank. A baffle, 33, between the pipe, 13, and the chamber, 15, serves to retain dust. An air nozzle, 18, projects into each chamber, 15, and the outer end of the nozzle is formed as a peep-hole, 18′, closed with a plate of mica, through which the combustion in the chamber, 15, can be watched. The chambers, 15, on opposite sides of the tank are out of line with one another, and a peep-hole, 20, between each nozzle enables the combustion in each chamber to be watched from the opposite side of the tank. The products of combustion escape through two flues, 30, and pass through flues, 27, 28, 26, to the stack. Another flue, 23, situated between the flues, 26, 27, is connected by pipes, 19, to the nozzles, 18, and is also connected to a blower for supplying air. Thus the air supply is heated by the burnt gases escaping from the tank. The two flues, 30, are preferably situated at opposite corners of the tank in order to receive an even distribution of the gases burning in the tank.

G. D.

247. Glass Furnaces. T. C. Moorshead, London (Brit. Pat., No. **173794**, July 8th, 1920).—In a glass furnace having a refining chamber, 3, in communication with a melting chamber, 1, the refining chamber is surrounded by a rotary annular delivery trough, 6, which is exposed at one point to allow access of the gathering machines.

H. G. C.

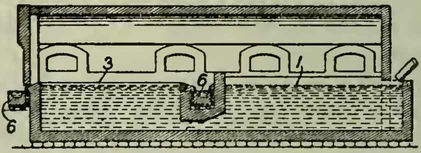


Fig. 143.

248. A Tank Furnace for Making Flint Glass. R. Good, Washington, Pa., Assignor to the Hazel-Atlas Glass Co., W. Va. (U.S.A. Pat., No. **1421211**, June 27th, 1922. Filed December 1st, 1919, No. 341733).—The invention consists of a continuous tank furnace for making the finer grades of glass such as are usually made in covered pots. The tank, shown in longitudinal section in Fig. 145, is built up of blocks which preferably rest on, and are surrounded by, a layer of insulating material, such as sand, working holes, 15, being provided at one end as usual. Within the tank, and at a distance below the crown, 7, is an arch, 8, and an end wall, 16, of refractory material, which, with the crown, 7, form a combustion chamber, 9, to which fuel and air are admitted by burners, 17, and ports, 18. At one end, 10, this chamber is enlarged, and cones, 11, of refractory material extending through the crown and the arch, 8, are situated in the enlargement, 10. In operation, combustion takes place in the chamber, 9, and cones, 11, are intensely heated. The usual mixture of batch and cullet is fed regularly into the cones, and when fused runs down into the body of the tank where it is further refined as it moves down

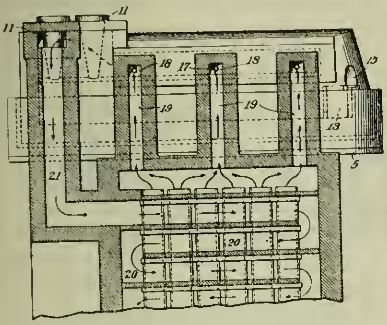


FIG. 144.

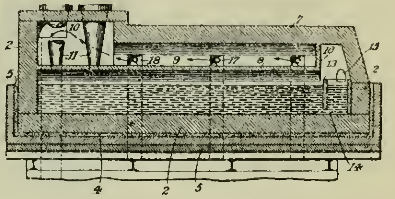


FIG. 145.

to the working holes, 15, by the heat radiated from the arch, 8. The hot gases pass out of the chamber, 9, into a flue, 21, and circulate around recuperator tubes, 20, through which the air proceeding to the ports, 18, passes. G. D.

249. A Rotating Lehr and the Method of Operating it. J. BAILEY, Assignor to CORNING GLASS WORKS, New York (U.S.A. Pat., No. **1416595**, May 16th, 1922. Filed March 17th, 1919, No. 283062).—The invention comprises a rotary chamber, preferably of circular cross section, and means for heating its interior, preferably but not necessarily by conduction through the chamber walls. If articles which are circular or substantially circular in cross section are fed into one end of this rotating chamber, gravity, by causing them to remain at the bottom of the chamber, will cause them to roll on the inner side of the wall, thus exposing them uniformly to the heat of the chamber. If the articles are cylindrical, the rotating chamber should be conoidal so that the rolling of the glassware on the inside of the cone causes a progressive motion along the length of the chamber. If the articles themselves are substantially conoidal, this progressive motion is obtained by using a cylindrical rotating chamber, in which case the movement is towards the narrow end of the conical articles. Progressive motion obtained as described dispenses entirely with articulated driving or carrying elements.

Fig. 146 indicates a form of lehr in which the idea is embodied, and is adapted to the annealing of electric lamp bulbs. It consists of a cylindrical metallic pipe, 10, which forms the heating chamber and is mounted in suitable end bearings, 11. Throughout the greater portion of its length the pipe is within a chamber, 16, preferably lined with heat-insulating material, 17, and provided with burners, 18, by which it may be heated. Near one end the pipe carries a sprocket wheel, 20, driven by a chain, 21. An inclined trough, 30, is adapted to feed the bulbs into the entrance end of the chamber and a second trough, 31, is provided to carry away the bulbs from the delivery end.

Since the progress of a bulb through the lehr is dependent on its rotation, it is evident that broken bulbs which cannot rotate may be separated from the others by mounting the heating tube at an angle to the horizontal and feeding the bulbs into the lower ends. By this means, only complete bulbs will climb up the incline and the defective ones will slide out of the lower end.

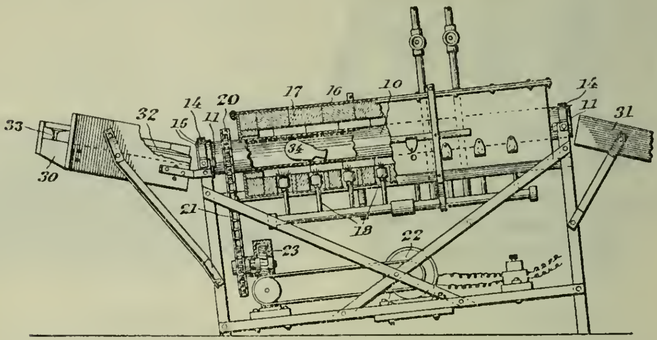


Fig. 146.

S. E.

250. **Apparatus for the Heat Treatment of Articles.** D. E. Grey, Corning, New York, Assignor to Corning Glass Works, Corning, New York (U.S.A. Pat., No. **1372420**, March 22nd, 1921. Filed January 8th, 1920, No. 350210).—This patent refers to the apparatus described in the preceding abstract (J. Bailey, U.S.A. Pat., No. 1416595). S. E.

VIII.—Chemical Analysis.

251. **Tentative Methods for Ultimate Chemical Analysis of Glass.** (*J. Amer. Cer. Soc.*, 1922, **5**, being the Year Book for 1921–22, p. 50.)—The descriptions given covered the main points of silicate analysis, but references for details were given to Bulletin 700, U.S. Geol. Survey on "Analysis of Silicate and Carbonate Rocks" (W. F. Hillebrand) and to "Treatise on the Ceramic Industries," Vol. 1 (1913) (J. W. Mellor).

Notes were given on the preparation and grinding of samples, the careful checking of results, and the preparation of solutions required. The methods of analysis were outlined briefly as follows:

Moisture, determine at 105—110°.

Ignition loss, determine on heating to a temperature of 900—1000°.

Silica, fuse 0·5 gm. of the sample with 5 gm. of Na_2CO_3, then extract with water, add 20 c.c. of conc. HCl, evaporate to dryness, take up with HCl and water, filter and wash free from chlorides. Evaporate the filtrate again for residual silica. Heat the combined silica in a blast, weigh, then evaporate with HF. Retain the residue, and add the alumina precipitate to it.

Alumina.—Precipitate as usual with $NH_4 \cdot OH$, in presence of NH_4Cl, scumming carefully. Ignite precipitate and weigh with the residue from silica.

Iron Oxide.—Fuse the alumina precipitate with potassium bisulphate, correcting for silica. Make up the solution in water to 250 c.c., and reserve 50 c.c. for the estimation of titania. Reduce the remainder of the solution with pure Zn and H_2SO_4, and titrate with standard $KMnO_4$ solution (1 c.c. $\equiv$ 0·001 gm. of Fe_2O_3).

Titania.—Determine colorimetrically in the 50 c.c. of solution reserved.

Lime.—To the boiling filtrate from the alumina, add 5 c.c. of acetic acid, and 1 gm. of oxalic acid dissolved in a little water. Add slight excess of $NH_4 \cdot OH$, boil, and cool. Filter and wash the precipitate with dilute $NH_4 \cdot OH$. Dissolve in dilute HNO_3, and reprecipitate. Filter, wash, and ignite to CaO.

Magnesia.—Precipitate as $Mg_2P_2O_7$ from the filtrate from the lime precipitation, by means of sodium-ammonium-phosphate. Collect, and ignite in a Gooch crucible.

Alkalies.—Use the J. Lawrence Smith method, namely, fusion with NH_4Cl and $CaCO_3$. The potassium is separated as chloroplatinate. V. D.

252. Limits of Accuracy in Chemical Analyses. E. Selch and R. Garstenauer (*Sprechsaal*, 1921, **54**, 37, 432).—A sample of Hohenbocka sand received sealed from the sellers and analysed in the authors' laboratory was returned as having the percentage composition given in analysis I. A second sample drawn from stock at a glassworks and analysed in another laboratory was returned as shown in analysis II.

Analysis I.	
Silica	99·85
Alumina	0·05
Iron oxide	0·011
Lime	0·01
Alkalies	0·02
Loss on ignition	0·10
Total	100·041

Analysis II.	
Silica	98·600
Alumina + Zirconia	0·331
Iron oxide	0·010
Lime	0·158
Magnesia	0·190
Copper	0·093
Sulphuric acid	0·082
Sulphur	0·018
Alkalies	0·220
Total	99·702

A check analysis of the first sample by the second author of this paper entirely confirmed the original result, but as no duplicate of the second sample was available the actual analysis could not be checked.

The second analysis was done in a laboratory not specialising in silicate analyses. The authors pointed out that the results in analysis II were surprising, both qualitatively and quantitatively, to anyone acquainted with Hohenbocka sand, but as the sample was drawn from a glassworks stock it was possible that it had become contaminated either in transit or during storing. Their chief criticism was directed to the absurdity of returning the analysis to three decimal places, as this gave a false impression of the accuracy of the result to anybody not specially experienced in silicate analysis. Although this accuracy was assumed, the sum total of the constituents showed a deficit of 0·3 per cent., and the "loss on ignition" was omitted entirely.

The authors point out that, in the general method of silicate analysis, 1 gm. of the sample was used. The best analytical balances were only accurate to 0·0001 gm. and a weighing error of 0·1 mg. meant an error in the analysis of 0·01 per cent. Accuracy was only obtainable theoretically to the second place of decimals, and in practice this could not be attained. The various constituents could not be separated completely nor in a perfectly pure condition. Occlusion, hygroscopicity, the influence of the heating gases, etc., prevented this, nor were the reagents used obtainable in this degree of purity. It was impossible to get analytical results accurate in the second decimal figure and therefore ridiculous to return results to three decimal places.

The single exception was in the case of the iron oxide, as this was determined colorimetrically or volumetrically, and therefore the weighing error was not so pronounced. J. H. D.

253. Qualitative Separation and Detection of Uranium, Vanadium, and Chromium when present together. P. E. Browning (*J. Amer. Chem. Soc.*, 1921, **43**, 114).—A solution containing chromic and vanadic acids and a salt of uranium was rendered slightly alkaline by the addition of ammonia, then slightly acid by means of acetic acid. The addition of ammonium phosphate precipitated the uranium. The precipitate was filtered off, washed, and tested by the addition of a drop of potassium ferrocyanide solution. The presence of uranium was indicated by a brown stain. Sulphur dioxide was passed into the filtrate to reduce the acids, and the excess was boiled off. Bromine was added, and the excess boiled off again, and thus the vanadium was oxidised to vanadic acid, leaving the chromium unaffected. The chromium was then precipitated as a mixture of hydroxide and phosphate by ammonia. The filtrate was rendered alkaline by ammonia, and saturated with sulphuretted hydrogen, producing the pink or violet vanadium oxysulphide. V. D.

254. New Method for the Estimation of Potassium. St. Minovici and C. Kollo (*Bull. Soc. Chim. România*, 1921, iii, 17; *Chem. Abstracts*, 1921, **15**, 3044).—The solubility of $KHC_4H_4O_6$ in a saturated solution of $NaHC_4H_4O_6$ or in presence of excess $H_2C_4H_4O_6$ solution which had been saturated with the potassium salt, was inappreciable. Pure water at 20° dissolved 0·57 per cent. of its weight of $KHC_4H_4O_6$, but only 0·01 per cent. was dissolved in a 7·5 per cent. solution of $NaHC_4H_4O_6$, and less in a saturated solution. For the estimation, about 5 c.c. of water were used to dissolve 0·25 gm. of the potassium salt, 0·5 to 0·6 gm. of powdered $NaHC_4H_4O_6$ was added, and the mixture allowed to stand for one hour with occasional stirring. Five c.c. of 5 per cent. $H_2C_4H_4O_6$ solution (which had been allowed to stand in contact with 1 gm. of $KHC_4H_4O_6$ for each 100 c.c. of solution) were added, and the mixture was filtered. The precipitate was washed twice by decantation with 5 c.c. portions of the acid to dissolve out the excess of $NaHC_4H_4O_6$ and then washed on the filter with 50 c.c. of a 1 : 1 alcohol and ether mixture to dissolve out the excess of tartaric acid. The precipitate could be weighed on a tared filter, or, preferably, dissolved in boiling water and titrated with standard NaOH solution, using phenolphthalein as indicator. To the weight of K_2O found, 0·005 gm. should be added to allow for the slight solubility of $KHC_4H_4O_6$. The separation could be done in the presence of sulphate and phosphate and gave satisfactory results. E. M. F.

255. New Method for the Estimation of Arsenic. J. Cribier (*J. pharm. et chimie*, 1921, **24**, 241; from *J. Inst. Metals*, 1922, **27**, 435).—A strip of filter-paper moistened with a 5 per cent. solution of mercuric chloride and then dried was stained yellow by arsenic hydride; a 10 per cent. solution of potassium iodide changed the colour on the paper to a permanent brown. By comparing the depth of this brown colour with that caused by a known amount of arsenic, quantities of arsenic from 0·001 to 0·0001 mgm. could be determined. The arsenious hydride, developed in a flask with zinc and sulphuric acid, passed into a vertical glass tube which was fitted to the flask through a cork. In the glass tube, which was wrapped in paper to exclude light, was a strip of mercuric chloride paper 12—15 cm. long and 0·5 mm. wide. Two to six hours were required for the volatilisation of the arsenic, after which the test-paper was treated with the potassium iodide solution. E. M. F.

256. The Detection and Estimation of Small Quantities of Nickel and Cobalt in Silicate Rocks. O. Hackl (*Chem. Zeitung*, 1922, **46**, 385; from *J. Chem. Soc.*, 1922, **122**, ii, 458).—A large quantity of the rock sample was digested with aqua regia until no more of the material could be dissolved; the solution was then diluted and filtered. Nitric acid was removed from the filtrate by evaporation to dryness. This residue was dissolved in hydrochloric acid, diluted with water, and saturated with hydrogen sulphide. After filtering off any precipitate, the filtrate was rendered ammoniacal and again saturated with hydrogen sulphide. To this saturated solution was added a large excess of a 5 per cent. solution of hydrochloric acid, the mixture allowed to stand, and finally filtered after the precipitate had settled.

The sulphide precipitate was well washed with dilute hydrochloric acid solution saturated with hydrogen sulphide.

After dissolving the precipitated sulphides in aqua regia, the solution was divided into two portions. To one portion was added tartaric acid, the resulting solution was rendered faintly ammoniacal and tested for nickel by the addition of a solution of α-dimethylglyoxime. The other portion, after the removal of any trace of iron present, was tested for cobalt by Vogel's thiocyanate reaction or by means of nitroso-β-naphthol.

If a quantitative separation were desired, the sulphide precipitate, obtained as previously indicated, was dissolved in aqua regia and all traces of iron were removed by three precipitations with ammonia or barium carbonate. The nickel and cobalt sulphides were again precipitated, washed as before, ignited to oxides, and finally reduced to metals and weighed as such. Either of the metals could then be estimated separately and the other found by difference.

The residue from the first treatment with aqua regia should be evaporated with hydrofluoric acid and tested for nickel and cobalt as already indicated. F. W. H.

257. The Separation of Zinc by means of Ammonium Phosphate. G. Luff (*Chem. Zeitung*, 1922, **46**, 365; from *J. Chem. Soc.*, 1922, **122**, ii, 456).—Zinc might be quantitatively separated from magnesium and manganese by precipitation of the two last-mentioned substances, using ammonium phosphate. The solution of the metals should contain at least one-fifth of its bulk of ammonia (density 0·923). In the case of the separation of zinc and manganese, the operation must be carried out in an atmosphere of hydrogen to prevent precipitation of manganese dioxide.

Iron and aluminium could be precipitated as phosphates free from zinc by the addition of ammonium phosphate to a solution containing at least one-fifth of its bulk of glacial acetic acid.

The zinc was obtained from the filtrates by rendering them neutral to litmus, using hydrochloric acid in the first case and ammonia in the second. F. W. H.

258. A New Method for the Volumetric Determination of Nickel. Gino Zuccari (*Boll. Chim. Farm.*, 1920, **59**, 25; from *Chem. Abs.*, 1921, **15**, 2601).—Nickel could be precipitated quantitatively from acid solutions of its salts by means of sodium nitroprusside, and in this way separation from ferric iron, aluminium, zinc, tin, lead, and manganese could be effected. In a quantitative estimation a 0·5*N* solution of $Na_2Fe(CN)_5NO+2H_2O$ was used, or an empirical solution containing 50·771 gm. per litre, of which 1 c.c.=0·01 gm. of metallic nickel. The solution was added to the nickel solution dropwise from a burette, with constant stirring. The end of the reaction was indicated when the precipitate had assumed a clear ash colour, and the supernatant liquid was colourless. A drop of the solution was filtered, tested with Na_2S, and absence of any black colour denoted complete precipitation. A slight excess of the reagent imparted a pale violet colour to the solution. The best results were obtained when the nickel solution contained not less than 1·5 per cent., and was distinctly acid. $Na_2Fe(CN)_5NO$ also precipitated cobalt, but this precipitate was insoluble in ammonia, whereas the nickel precipitate was soluble.

V. D.

259. The Qualitative and Quantitative Determination of Nickel and Cobalt. Motooki Matsui and Tadasu Nakazawa (*Mem. Coll. Sci. Kyoto Imp. Univ.*, 1920, **4**, 265; from *J. Inst. Metals*, 1921, **27**, 441).—Complete reaction took place between washed nickel hydroxide and a 1 per cent. alcoholic solution of dimethylglyoxime, on shaking, whereas cobalt was only partly converted and ferric hydroxide was not attacked. The nickel dimethylglyoxime could be separated from the unchanged hydroxides by treatment with excess dimethylglyoxime solution, boiling for a short time, adding a large excess of water, cooling, and then adding ether. The unchanged hydroxides were left below, while the nickel compound floated on top.

A very delicate test for cobalt dimethylglyoxime, in neutral solutions, consisted in the addition of a drop or two of yellow ammonium sulphide, when an intense red colour was given. Ammonia rendered the test less delicate.

Quantitative deposition of nickel from the solution of the dimethylglyoxime compound in sodium hydroxide could be effected by electrolysis, if the solution did not contain more than 0·05 gm. of Ni per 100 c.c. For the deposition of cobalt, ammonia must be used in place of sodium hydroxide. The two metals were separated by precipitation with dimethylglyoxime in presence of sodium acetate, then the solution was electrolysed as described above.

V. D.

260. A New Method for the Detection and Estimation of Cobalt. S. A. Braley and F. B. Hobart (*J. Amer. Chem. Soc.*, 1921, **43**, 482).—In the absence of copper and iron, cobalt could be detected by the brown coloration given to the solution containing acetic acid and sodium acetate, on the addition of dimethylglyoxime. The method could also be used to estimate cobalt colorimetrically. V. D.

261. Nitroso-R-salt, a New Reagent for the Detection of Cobalt. H. S. van Klooster (*J. Amer. Chem. Soc.*, 1921, **43**, 746).—The reagent was prepared by dissolving 35 gm. of the pure salt (sodium β-naphthol-3 : 6-disulphonate) in 400 c.c. of water, acidifying with 10 c.c. of hydrochloric acid (sp. gr. 1·19), cooling to 10°, then adding, drop by drop, a solution of sodium nitrite, 7·2 gm., in 20 c.c. of water, with constant stirring. The thick, orange-coloured precipitate was collected, stirred well again in water, again filtered, and washed with water and alcohol. Fan-shaped golden crystals of this nitroso- or oximino-compound crystallised out from an aqueous solution, the solubility in water at 18° being 2·6 per cent. The aqueous solution and the solid were stable. The use of this salt afforded a very delicate test for cobalt, a deep red cobalt compound, $(C_{10}H_5O_8NS_2Na_2)_3Co$, being produced, giving results even when one part of cobalt was present with 200 parts of nickel. A solution of the salt to be examined was made, the strength being 1·5, or 2 per cent. To 2 c.c. of this solution was added a gm. of sodium acetate and 2 c.c. of a 0·5 per cent. aqueous solution of nitroso-R-salt. The whole was boiled gently, then 1 c.c. of concentrated nitric acid was added slowly, the boiling being continued for a minute. The compounds formed by other metals were decomposed by the acid, and the deep red cobalt compound was very pronounced. Ferrous salts gave a green, and nickel salts a brownish-yellow compound when treated with the R-salt, but these were destroyed under the conditions of the test for cobalt. V. D.

262. Tervalent Manganese. J. MEYER and R. NERLICH (*Zeitsch. anorg. Chem.*, 1921, **116**, 117).—A delicate method for detection of manganese consisted in adding ammonia to the solution, collecting the precipitate, spreading it on the filter-paper, on a watch glass, and adding a few drops of ortho-phosphoric acid. A characteristic reddish-violet coloration was produced in the precipitate when manganese was present. V. D.

IX.—Machinery for the Working of Glass.

263. A Glassworker's Pneumatic Pipe. (*Times Trade Supplement*, 1922, Sept. 30th; see also *Glasindustrie*, 1922, **22**, 175).—W. Lippold, of Dresden, has devised a blowpipe in which the irregular blowing by mouth is replaced by mechanical blowing. Fig. 147 shows the essential construction. The compressed air is used not directly, but is employed to draw, by a jet action, a small stream of air into the pipe. A compressed air reservoir is combined with the pipe, which is, therefore, independent of any air hose, and can be turned in any direction as easily as the ordinary mouth blowpipe. Regulation of the air stream can be effected very precisely by a small valve actuated by a press button which is operated either by the finger or by the chin of the blower. W. C. S.

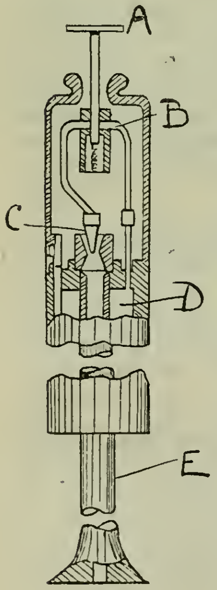


FIG. 147.

264. A Device for Mechanically Forming Glass Handles on Baskets, etc. F. M. BIGELOW, Jeannette, Pa. (U.S.A. Pat., No. **1390754**, September 13th, 1921. Filed July 9th, 1920, No. 394981).—The object of this invention was to provide a means for forming the members of glass baskets and similar articles having attached handles of the bale or loop form, such handles being moulded in one piece with the body of the article. A mould consisting of three sections was used, the dividing line between the top and intermediate sections being in an inclined plane. Between the top and intermediate sections was provided a channel into which the molten glass was pressed to form the handle. Before the glass was set, the top section of the mould was removed, and the pliable handle bent into an upright position, which permitted the intermediate section of the mould to be withdrawn. S. E.

265. A Mould for Pressing Sparking-plugs. F. A. Howard, Swissvale, Pa. (U.S.A. Pat., No. **1405034**, January 31st, 1922. Filed July 28th, 1919, No. 313913).—The mould consists of a bottom, *A*, and two sections, *B*, hinged together and provided with moulding spaces, *E*, a cavity, *D*, for receiving the metal, and passages, 14, connecting the spaces, *E*, and *D*.

The invention consists chiefly in providing sockets, 17, 20, which grip the electrodes, *F*, of the plugs and keep them properly centred during the pressing operation. The passages, 14, are also made at an acute angle to the spaces, *E*, so that as the metal is pressed from the cavity, *D*, through the passages, 14, it will flow downwards into the spaces, *E*, and any tendency to bend or distort the electrodes will be minimised. G. D.

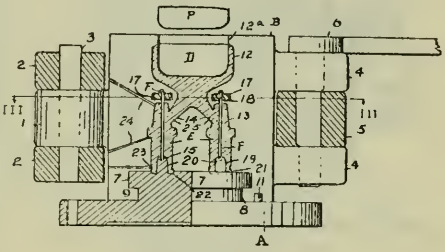


Fig. 148.

266. Bottle-blowing Machine. E. Hughes, London, J. Middleton, Leeds, B. Wilson, London, and Glassworks, Ltd., London (Brit. Pat., No. **174880**, April 21st, 1921).—In a turnover bottle-blowing machine of the kind described in Specification 162029, the suction passage, 5, of the turnover head, 2, terminates in a spring valve, 10, which slides over the surface of the stationary frame, 1, and registers with a suction port, 9, when the mould, 4, is in the charging position. Blowing-air is controlled by a tap, 8. H. G. C.

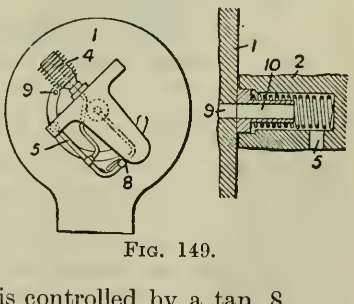


Fig. 149.

267. Automatic Machine for Blowing Bottles. H. Hillman, Gross-Räschen, Niederlausitz, Germany (Brit. Pat., No. **172947**, December 2nd, 1921. Convention date, December 18th,

1920. Not yet accepted).—Relates to a machine of the Owens type for blowing bottles. According to the invention, the cams which control the suction apparatus are mounted on a fixed central hollow column, 11, and the cams which control the blowing and other later operations are mounted on an outer column, 12, which can be rotated somewhat, so as to vary the time elapsing between the suction and blowing operations according to the size of bottle being made. The ring mould, 30, is lowered between the open halves of the parison mould, 25, so as to bring the blank quickly and without distortion into the blow mould, 27. The neck rod or plunger, 51, is operated automatically by the vacuum and pressure. To avoid mould marks in the finished ware, it is blown twice, the blow mould being opened and the ring mould rotated between the blowings. To ensure that only very fluid glass shall be drawn up into the parison mould, the surface of the metal in the tank is skimmed in of the mould. H. G. C.

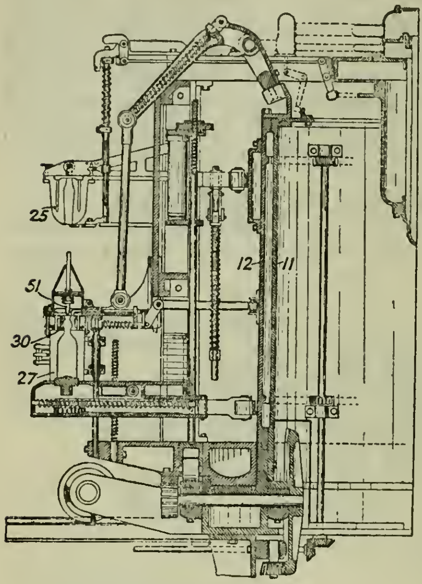


Fig. 150.

268. Semi-automatic Bottle-blowing Machine. W. J. Mellersh-Jackson, London, and C. J. Root, Terre Haute, Ind., U.S.A. (Brit. Pat., No. **176017**, August 24th, 1920).—Relates to a semi-automatic pneumatically operated glass bottle blowing machine, of the type wherein the operation is started by the gatherer striking a valve lever with the gathering-iron when charging each parison mould. The molten metal is introduced through a guide funnel, 212, into the parison mould, *A*, whilst the nipple, 57, is in its raised position, and, after the removal of the guide, 212, a blowing-head, 280, is brought down to compress the metal. To facilitate centring the nipple, 57, it is held in place on its rod, 266, somewhat loosely by a screw collar, 264. Passages, 272, 273, are provided for air-cooling the nipple. As the moulds rotate round the central column, the parison mould, *A*, is inverted by gearing, 46, on the mould engaging a fixed toothed segment and is opened. The blowing-mould, *D*, is raised by a pneumatic cylinder, 144, from the position shown on the right of Fig. 151 to that shown on the left, and the parison is enclosed in it and blown by a blowing-head, 192, as usual. Reference has been

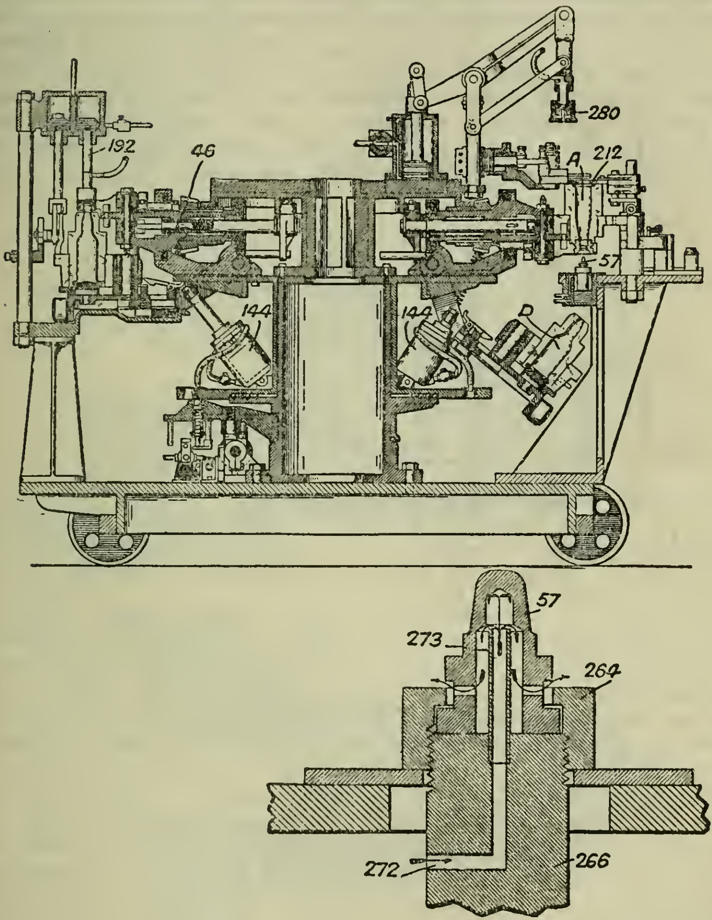


Fig. 151.

directed by the Comptroller to Specifications 127995, 142156, and 144344.

H. G. C.

269. Glass Delivery Device. Howard Automatic Glass Feeder Co., and G. E. Howard, both in Butler, Pa., U.S.A. (Brit. Pat., No. **174311**, July 13th, 1920).—Relates to the delivery of uniform charges of molten glass from a tank furnace 1. The molten glass flows from the tank, 1, through a submerged opening, 13, over a weir, 18, to a space, 19, where the stream is divided by a block, 45, and flows in separate channels, 44, Fig. 152, to the discharge hole, 26. It is forced through this in drops by a hollow reciprocating plunger, 51, and cut off into charges by shears. The rate of flow through the hole, 13, is kept constant and independent of the varying level in the melting tank, 1, by means of a valve, 14, which is operated through levers, etc., from a pivoted float, 4.

Another device by the same inventors (Brit. Pat., No. **174097**, July 13th, 1920) relates to the delivery of uniform charges of molten glass from a tank furnace and consists in forming a gob or drop of glass by gravity flow through an outlet, accelerating this flow during the formation of the gob, then retarding the flow and severing the suspended gather from the parent body of metal.

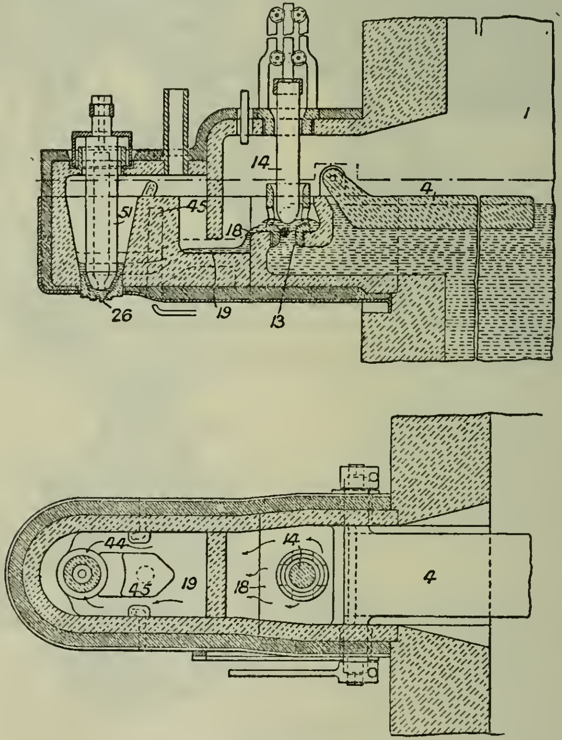


Fig. 152.

The molten glass flows from the tank, 1, Fig. 153, through a submerged opening, 13, over a weir, 18, to a space, 19, where the stream is divided by a block, 45, and flows in separate channels to the discharge hole, 26. It is forced through this in drops, 80, by a hollow reciprocating plunger, 51. The downward movement of the plunger forces the metal through the hole, 26, but on the upward movement, the flow is retarded and the stream is cut off into a charge by shears, 79. The rate of flow through the hole, 13, is kept constant and independent of the varying level in the melting tank, 1, by means of a valve, 14, which is operated through levers, etc., from a pivoted float, 4. After a charge is cut off from the stream, it passes along a trough or deflector, *D*, which is so placed that the charge is hanging freely at the time of severance, but if the glass becomes hotter and tends to stretch unduly, the trough supports the charge and prevents it from stringing out. Specification 174311 is referred to.

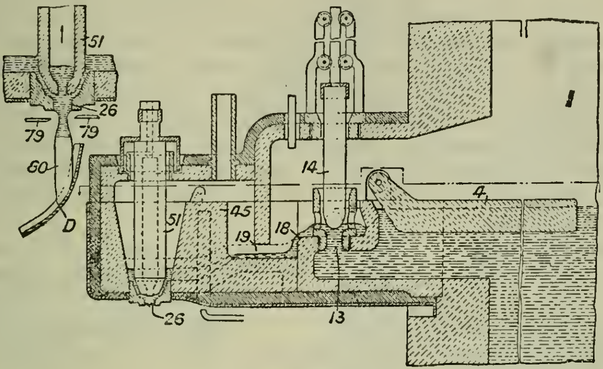


FIG. 153.

Reference has been directed by the Comptroller to Specifications 113665, 118581, 129822, 142785, 142786, and 143159. H. G. C.

270. A New Glass Feeding Apparatus. K. E. PEILER, Hartford, Connecticut, Assignor to HARTFORD-FAIRMONT CO., Canajoharie, New York (U.S.A. Pat., No. **1401921**, December 27th, 1921. Filed December 30th, 1916, No. 139767).—A spherical or cylindrical mass of refractory material secured to the end of a rotatable shaft, is held in a trough or forehearth containing glass in such a way that on one side there is only a working clearance while on the other side there is space for the free passage of glass. The shaft carrying this propeller head is rotated intermittently, the rotation being in that direction which will allow the glass to be drawn freely towards the delivery spout of the trough or forehearth. Since the glass cannot escape on the other side of the head, and rejoin the mass of glass in the tank, it is piled up until it is high enough to flow over the spout. By regulating the speed of the propeller, and the intervals of its "dwell," with proper relation to the viscosity of the glass, the size of the ejected gobs may be controlled. S. E.

271. Apparatus for Gathering Molten Glass. J. B. GRAHAM, Evansville, Indiana, Assignor to the OWENS BOTTLE MACHINE CO., Toledo, Ohio (U.S.A. Pat., No. **1353953**, September 28th, 1920. Filed January 18th, 1918, No. 143002).—The feeding device described in this specification is similar to that described in the abstract except that the movements of the various parts are caused and controlled by compressed air operating on pistons connected to those parts. The synchronisation is obtained by cams operating valves in the compressed air system. S. E.

272. Glass Delivery Device. A. N. Cramer, Toledo, O., U.S.A., Assignor to the Owens Bottle Co., Toledo (Brit. Pat., No. **175949**, May 30th, 1921. Convention date, February 23rd. Not yet accepted).—In apparatus of the reciprocating-plunger type for delivering molten glass from an orifice, means are provided for manually adjusting the movements of the plunger during operation, for shearing the extended metal, and for timing and adjusting the shearing mechanism, both simultaneously with the plunger and also independently. The plunger, 37, Fig. 154, works in a boot, 26, extending from the wall of the furnace, and is operated by a lever, 48, from a cam, 47. The mean position of reciprocation can be adjusted during working by raising or lowering an arm, 52, by means of a hand wheel, 59, connected by a universal joint, 60, to a screwed rod, 55. The length of the stroke can be adjusted by varying the position of the fulcrum, 49, of the lever, 48, and the character of the stroke can be varied by the cam, 47, which is formed with three relatively adjustable parts, 61, 62, 63. The portion 61 effects an initial rapid upward movement of the plunger, which is succeeded by a pause due to a rest portion, 65, and by a slower upward movement due to the portion 62. A second rest portion, 66, allows the plunger to pause at the top of its stroke, and the final portion, 63, allows the plunger to descend under its own weight. The cam, 47, is rotated from driving shafts, 111, 116, Fig. 155, through the intermediary of a worm-wheel, 117, 118, and a chain drive, 119, 120. The shearing

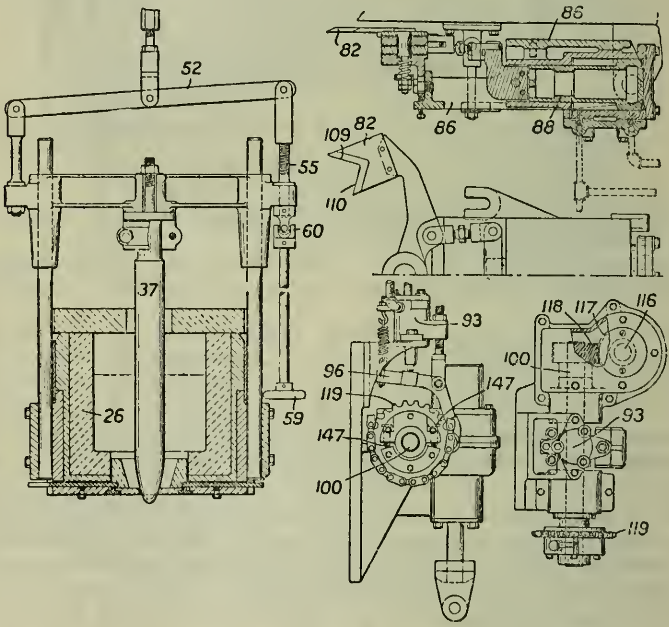


Fig. 154.

mechanism comprises pneumatically operated shears, 82, Fig. 854, mounted beneath the boot and having cutting-edges, 109, 110, adapted to grip the metal at four points simultaneously. A frame, 86, on which the shearing mechanism is mounted, is pivotally connected to the boot, so that the mechanism can be swung down to permit the shears to be changed or adjustments made. The operation of the piston, 88, driving the shearing mechanism is controlled by a distributing-valve within a casing, 93, Fig. 154, which is actuated through a lever, 96, from an adjustable cam on the shaft, 100. The sprocket-wheel, 119, on the end of the shaft, 100, is slightly adjustable by means of screws, 147, so that an earlier or later operation of the plunger relative to the operation of the shears may be effected. To permit of adjustment of the timing of the plunger and shears relatively to the moulds, 112, which are carried on a table, 113, revolving in fixed relationship with the shaft, 111, an adjusting-screw, 133, is provided by means of which the shaft, 116, can be rotationally adjusted relatively to the shaft, 111. The flow of metal to the boot is controlled by a valve, 72, Fig. 155, and an equalisation of the temperature of the glass round the plunger, 37, is secured by an island or dividing wall, 80, in the boot.

H. G. C.

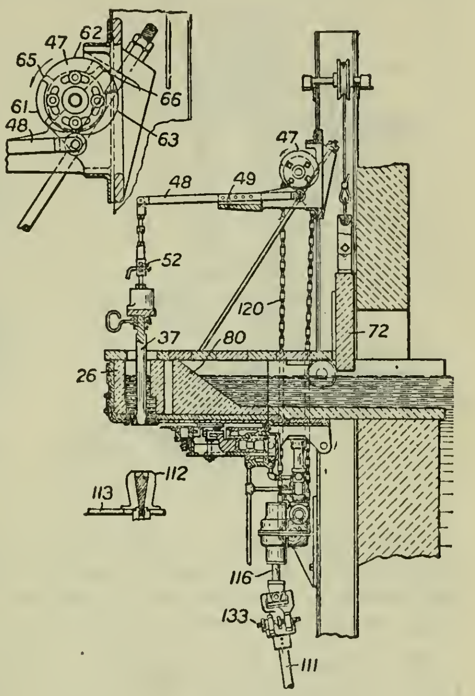


Fig. 155.

273. Glass Delivery Device. W. J. Miller, Swissvale, Pa., U.S.A. (Brit. Pat., No. **172634**, December 6th, 1921. Convention date, December 6th, 1920. Not yet accepted).—Relates to apparatus for delivering molten glass in uniform charges from a melting tank, *A*. According to the invention, the molten glass flows from a hole, *B*, and is cut off by shears, *M*. After each severing operation, a plug, *H*, is pushed into the hole, *B*, so as to arrest the flow and chill the glass in the hole. The plug, *H*, is then withdrawn and swung aside and the flow of glass recommences as soon as the chilled glass is remelted by contact with the mass in the furnace. A plunger, *E*, may be used to assist in expelling the glass. The cycle of operations is shown in Fig. 156.

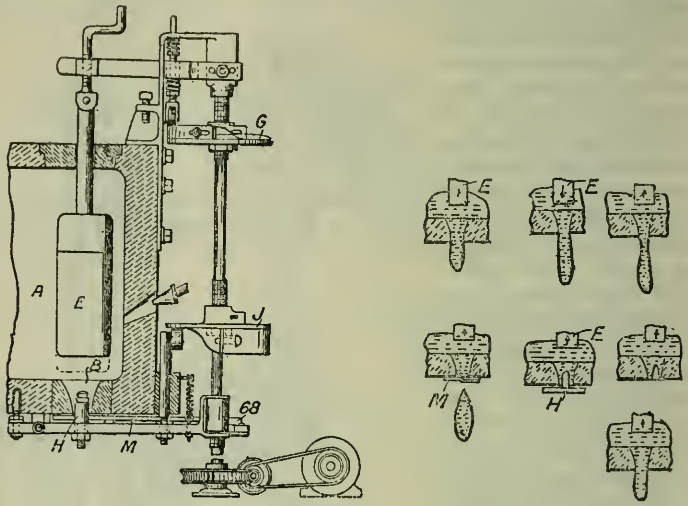


Fig. 156.

The plug, *H*, may be of graphite and may be electrically heated or water-cooled, as found desirable. The plunger, *E*, plug, *H*, and shears, *M*, are operated by adjustable cams, *G*, *J*, 68, springs being employed to cushion their action. H. G. C.

274. Process and Apparatus for Feeding Glass. W. J. Miller, Swissvale, Pa. (U.S.A. Pat., No. **1413757**, April 25th, 1922. Filed December 6th, 1920, No. 428753).—A shallow extension, *A*, of a glass tank is provided with an outlet orifice, above which a plunger, *E*, operates, and below which is situated a pair of shears, *L*, for severing the flowing glass at such intervals as to permit gatherings to form. A push-back or stopper mechanism, *H*, is provided, and acts between the shearing operations to interrupt temporarily the flow of glass through the outlet port. This push-back mechanism is arranged to enter the outer end of the discharge port, thus forcing a chilled neck of glass inwardly towards the zone of very hot glass, the impinging of the push-back against the glass chilling the surface, thereby forming a temporary dam of hardened glass, which is sufficient to hold up the flow of glass for a short time. The heat from the mass of glass eventually remelts this hardened portion, causing the obstruction to break

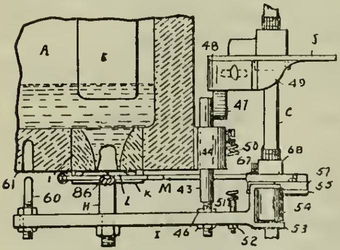


Fig. 157.

down and the hot glass to flow through in a stream to form the next gathering. The contact end of the push-back is rounded or tapered so as to impart an arched formation to the wall of chilled glass, and during the time it is in contact with the glass a rotary motion is imparted to it to prevent it sticking and to assist the backward movement of the glass. The push-back may carry a quantity of liquid such as water, which on coming in contact with the hot glass will vaporise and force the glass back into the port and act as a cushion between the glass and the end of the push-back. By alternately raising and lowering the plunger, gatherings of glass are intermittently forced out from the orifice. As soon as the glass stream becomes thin, the plunger starts to ascend and the shears sever the thinned portion. The shears promptly open to give clearance to the push-back, which is swung under the discharge port and elevated, the pin, 60, fitting into the socket, 61, and guiding the push-back, *H*, into the port. The push-back is removed before the plunger reaches the top of its stroke, and the hot glass remelts and breaks through the chilled wall before the downward movement commences. S. E.

275. A Glass Feeding Device. F. L. O. WADSWORTH, Pittsburgh, Pa., Assignor to BALL BROS. GLASS MANUFACTURING CO., Muncie, Indiana (U.S.A. Pat., No. **1375336**, April 19th, 1921. Filed June 27th, 1918, No. 242266).—In general the arrangement of the feeding device disclosed in this patent is similar to those described previously (see this JOURNAL, ABS., 1920, **4**, 114), the chief difference being in the arrangement of the cutting-off device. The knives are mounted close up to the orifice and operate along horizontal guides. The cutting edges are surmounted by two blocks of manganese steel each provided with a cavity, such that when the two are brought together they form a cup-shaped support for the end of the severed stream of glass. This cup-shaped support is not allowed to remain in contact with the glass for more than a very short interval, so that very little chilling of the surface layer occurs. It is claimed that by severing the stream of glass at the proper position, which is fairly close up to the orifice, and by shaping and only slightly chilling the depending stub of glass, the flow of glass from the tank may be retarded sufficiently to allow time for the different moulds to be brought to the charging position. S. E.

276. A Glass Feeding Device. K. E. PEILER, Hartford, Connecticut, Assignor to HARTFORD-FAIRMONT CO., Canajoharie, New York (U.S.A. Pat., No. **1349551**, August 10th, 1920. Filed December 30th, 1916, No. 139768).—Glass from a melting furnace is allowed to flow over a forehearth, 4, on to an acorn-shaped gathering head, 5, of refractory material secured on the end of a shaft, 6. This shaft is supported in bearings, 7, on the end of a swinging bracket, 8, which is pivoted on a shaft in line with the centre of the gathering head. By the rotation of the cam, 14, and the connecting arm, 12, this swinging bracket periodically carries the gathering arm to the position of the dotted line, 18, the inclination of the gathering head varying as shown on the right of Fig. 158. By means of gearing, the shaft, 6, is continuously rotated even during the periods when it is being elevated and returned to its normal position. The head, 5, and shaft, 6, are hollow so that air or other cooling agent may be admitted from the tube, 27. Shear blades, 33, are carried on an arm, 32, which is periodically rocked by a cam about the shaft, 31. Near the end of this inward swinging motion, the shanks of the blades engage a stop pin, 36, which causes the blades to close, thus severing the depending gob of glass, and allowing it to fall on the trough, 37, to be carried away to the mould, 38. S. E.

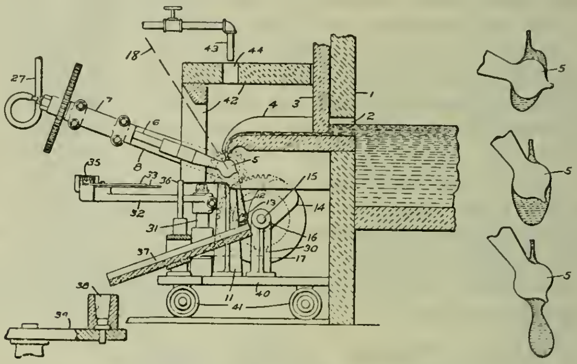


Fig. 158.

277. Apparatus for Feeding Charges of Hot Glass to Machines. R. la France, Toledo, Ohio, Assignor to the Owens Bottle Machine Co., Toledo, Ohio (U.S.A. Pat., No. **1390448,** September 13th, 1921. Filed March 20th, 1918, No. 223548).—The invention comprises certain improvements to the apparatus disclosed in the applications of J. B. Graham (see abstracts Nos. 271 and 278), and deals with a modified form of sectional cup, a modified operation of the knife and an improved form of knife. The opening at the bottom of the sectional cup is so narrowed, that the knife, after severing the stream of glass, may be withdrawn immediately, the walls of the cup being capable of supporting the glass as it accumulates, thus reducing to a minimum the chilling of the glass, and avoiding the scar often produced in the finished ware. The cutting-off knife is in the form of a disc which slides in contact with the base of the cup. The disc is mounted horizontally on a swinging arm, and is held by a spring against the base of the cup, thus avoiding the necessity of any fine adjustment, and automatically accommodating itself to any variations due to expansions. The blade is free to rotate on its pivot so that any wear on the cutting edge is uniformly distributed. S. E.

278. Method for Automatically Controlling the Temperature and Shape of Charges of Glass. J. B. Graham, Evansville, Indiana, Assignor to the Owens Bottle Machine Co., Toledo, Ohio (U.S.A. Pat., No. **1353907**, September 28th, 1920. Filed June 14th, 1917, No. 174697).—It is desirable when feeding glass into forming moulds that the charges of glass should have a uniform temperature throughout, and that they should be of a shape adapted to enter the blank mould easily. These points should receive particular attention when narrow-neck bottles are to be made.

According to the present patent, glass is allowed to flow from a furnace boot, 10 (Fig. 159), into a divided cup, 14, which may have water-cooling channels, 16. The glass is, for a short time, supported on the shears, 15, but when these are withdrawn, the accumulating mass, instead of dropping immediately, is temporarily supported by the walls of the cup, 14, owing to the fact that these walls are inclined outwards from the point *B*, forming an inverted frustum of a cone. A slight shoulder may be formed at the point *B*, thus aiding in supporting the mass of glass. Owing to the fact that the bottom, 15, is withdrawn at an early stage in the process, the glass at this point is only slightly chilled, and quickly becomes reheated, thereby allowing a cone of hot glass from the interior to break through and to flow downwards. This lower end, being very hot, is in the best condition for entering the neck end of a mould. When the charge of glass has fully gathered below the shoulder, *B*, the halves of the collecting cup, 14, are separated by the action of a cam, allowing the mass of glass to fall through the funnel, 44, into the forming mould, 38. The cup then closes almost simultaneously by a cam action, the knife, 15, severs the stream of glass and forms a temporary bottom to the cup.

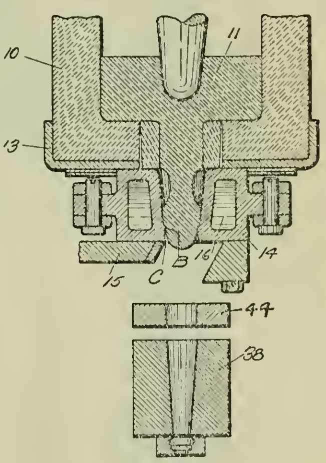


Fig. 159.

By allowing the entire mass of glass to fall into the mould in one compact gob, the objectionable lapping commonly produced by allowing it to run in a thin stream is avoided. S. E.

279. A Method for Forming and Transferring Gobs of Molten Glass. J. F. Rule, Toledo, Ohio, Assignor to the Owens Bottle Co., Toledo, Ohio (U.S.A. Pat., No. **1413788**, April 25th, 1922. Filed October 1st, 1919, No. 327648).—The invention relates to mechanism by which a flowing stream of molten glass is segregated, formed into gobs, and transferred to the moulds of a forming machine. The molten glass is allowed to run continuously from a tank extension, 10, (Fig. 160) into transfer cups, *A* and *B*, in which it is formed into suitably shaped gobs, and by which it is transferred to the parison moulds, 12. The transfer cups, *A* and *B*, are mounted on a carrier, which is rotatable about a horizontal shaft, by the action of the continuously rotating gear-wheel, 19, having teeth extending over a portion of its periphery. At each complete rotation of the gear, 19, the cup carrier is rotated a half-revolution and held stationary by one of the locking surfaces, 27. The gears are so proportioned that the cups are stationary the greater portion of the time, and are quickly rotated for the transferring of the gobs. Each transfer cup comprises a base and two hinged sections, which are opened and closed by the operation of the cam roller, 46, on the cam, 38, and the action of compression springs. The gob-forming cavity of the transfer cup is tapered so as to shape the gob substantially the same as the parison mould, and at the same time to prevent the premature discharge of the gob as the cup swings rapidly to the discharging position. The mechanism for severing the glass comprises a blade, 54, which is mounted in horizontal bearings, and made to reciprocate by the action of the cam, 57, and the lever, 58. The knife is advanced to sever the stream of glass immediately before the cups commence rotation, and during the time the transfer cups are changing position the knife acts as a temporary support for the oncoming stream of glass.

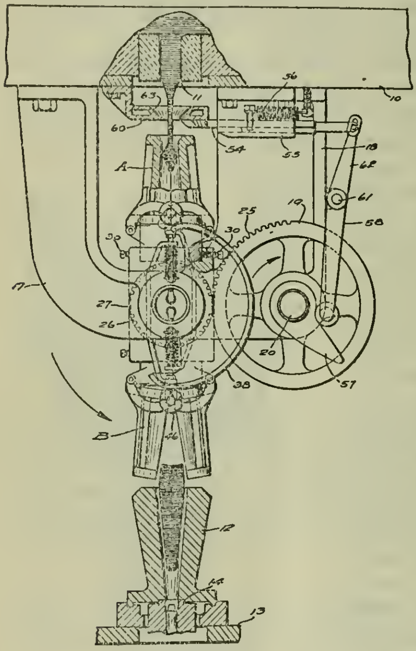


Fig. 160.

That portion of glass which enters the transfer cup last, and is therefore the hottest portion of the gob, enters the parison mould first and forms the neck of the bottle, an arrangement which is very desirable owing to the difficulty of properly shaping the neck unless the glass is very hot and free from local chilling. S. E.

280. Means for Delivering Molten Glass to Machines in Continuous Motion. R. la France, Toledo, Ohio, Assignor to the Owens Bottle Co., Toledo, Ohio (U.S.A. Pat., No. **1416725**, May 23rd, 1922. Filed July 10th, 1918, No. 244135).—A continuously rotating glass-working machine possesses important advantages over a machine with intermittent motion, but requires special provision for directing the glass into the moulds as they pass the charging station. This may be accomplished by allowing the glass to flow from the tank, through funnel guides travelling in a circular path above the moulds and remaining in register with them during the time occupied by the charging operation.

The glass in flowing from the tank is collected in a sectional cup, a temporary bottom for which is formed by a knife. This knife is periodically withdrawn and the cup sections separated, thus allowing the gob of glass to fall into one of a series of funnel-shaped guides, 19, mounted on a rotary carrier, 20. This carrier may be gear-driven at such a speed that the funnel guides travel at the same linear velocity as the moulds below them. These guides are also so spaced that each successive one registers with the consecutive moulds as they travel round on the machine table, 10. Each funnel has its mouth or receiving end elongated in the direction of its travel, thereby lengthening the period during which it is underneath the gob-forming cup. The lower end of the funnel may be less than the opening in the mould, 9, to compensate for the slight variations in the position of the funnel and mould in passing the charging station. S. E.

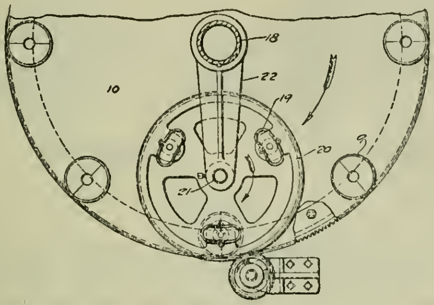


Fig. 161.

281. A Device to Prevent the Surface Chilling of Glass Charges emitted by a Feeding Device. K. E. Peiler, West Hartford, Connecticut, Assignor to Hartford-Fairmont Co., Canajoharie, New York (U.S.A. Pat., No. **1401922**, December 27th, 1921. Filed October 22nd, 1917, No. 197751).—The gobs of glass dropping from a discharging orifice are protected from contact with cold air by surrounding them with a curtain of flame, the direction of the individual flames being such that they do not impinge directly on the glass. Severe surface chilling is thereby avoided. S. E.

282. Means for Controlling the Discharge from Glass Tanks. E. S. Hutton, Lapel, Indiana (U.S.A. Pat., No. **1423220**, July 18th, 1922. Filed November 10th, 1919, No. 336835).—When temporarily shutting down a tank furnace fitted with a flow feeder, it is generally necessary to plug up the flow tube and chill the glass round the plug. When resuming work, the remelting of this glass is a difficult and prolonged operation. The invention described is to overcome this trouble by the use of a floating block, 20, which is made of a suitable refractory material, and is rather longer than the communicating opening, 14, between the melting tank and the discharge chamber. A groove, 21, is cut in this block, so that in the position shown in Fig. 162 the glass flows into the underside of the block and out at the top of the groove into the discharge chamber. When it is desired to stop the feeder working, the block, 20, is turned over to the position shown in the right of Fig. 162, thereby cutting off the flow of glass to the discharge chamber. The glass already in this chamber is worked out and the discharge orifice left clear of glass. S. E.

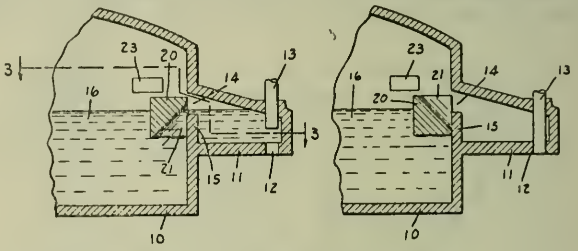


Fig. 162.

283. Means for Transferring Charges of Hot Glass to Machines. M. J. Owens, Toledo, Ohio, Assignor to the Owens Bottle Machine Co., Toledo, Ohio (U.S.A. Pat., No. **1350464**, August 24th, 1920. Filed April 15th, 1918, No. 228583).—Instead of having a single trough leading from a gob-forming device to a glass-working machine, a series of troughs is arranged about a central shaft, which is capable of rotation on its own axis. The multiple trough device is rotated step by step, to bring the conveying surfaces successively into the operative position. Water is sprayed on these channels while in one of the inoperative positions. S. E.

284. An Apparatus for Conveying Glass Charges to Moulds. J. Whittemore, Detroit, Michigan, Assignor to the Owens Bottle Co., Toledo, Ohio (U.S.A. Pat., No. **1399176**, December 6th, 1921. Filed August 23rd, 1918, No. 251067).—In its preferred form, this invention comprises inclined troughs or chutes leading to two or more forming machines; the upper ends of these troughs being one above the other. The charges of glass are alternately directed into these chutes by means of a hinged section, the upper or hinged end of which is in register with the delivery trough from the gob-forming apparatus whilst the lower end moves up and down to register with the several diverging troughs. The hinged distributing section may be actuated by a cam in timed relation to the gob-forming apparatus. S. E.

285. A Glass-discharging Mechanism. E. S. HUTTON, Lapel, Indiana (U.S.A. Pat., No. **1391957**, September 27th, 1921. Filed March 26th, 1920, No. 368867).—Into the wall at the working end of a tank is built a discharge member, 15, so that its upper surface is above the level of the glass, 12, while the larger portion of the block is below that level. Each end of the member, 15, projects several inches beyond the wall. This discharge member has a conduit, 20, extending horizontally from end to end, and opening into the glass tank by the submerged inlet, 21. Near the outlet, the conduit is elevated slightly above the normal level, 12, of the glass in the tank. The discharging of the glass is effected by air pressure exerted along the conduit, 30, from the cylinder, 35. By opening the valve, 37, air enters the conduit, 30, and forces the glass in the discharge end of the conduit, 20, to overflow and pass through the outlet, 24, into the mould, 40. The compressed air is only turned on long enough to permit of the discharge of the desired quantity of glass.

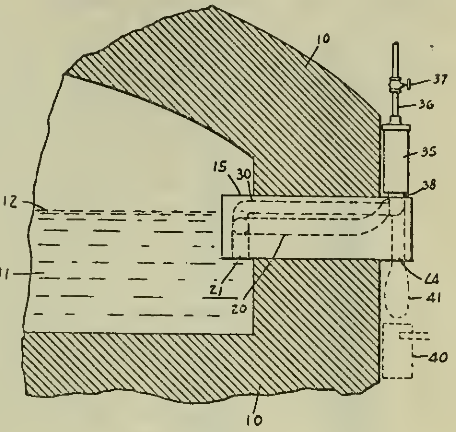


FIG 163.

A further patent by the same inventor (U.S.A. Pat., No. **1394677**, October 25th, 1921. Filed July 6th, 1920, No. 394241) relates to improvements in the construction and operation of the discharging device disclosed in patent No. 1391957.

The discharge member, 15 (Fig. 164), has a glass receiving chamber, 16, at its inner end, which is relatively large and has fitted into it an inlet bushing, 20, extending downwards into the body of the glass to any desired extent. In the chamber, 18, at the outer end of the device is a removable discharge bushing, 25, so constructed as to have an air-cooling

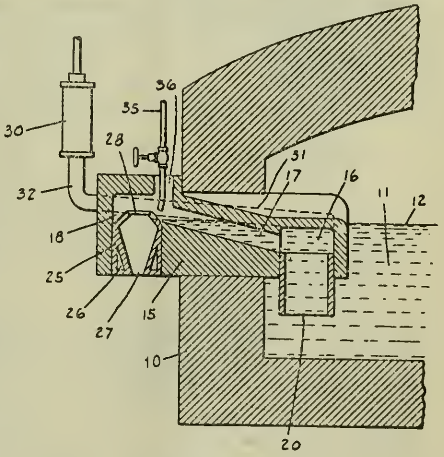


FIG. 164.

chamber, 26, surrounding the lower portion. The inlet and outlet orifices of these bushings may be varied to suit the work being done. S. E.

286. Glass Flow Controller. F. O'NEILL, Toledo, Ohio (U.S.A. Pat., No. **1413183**, April 18th, 1922. Filed October 17th, 1921, No. 508321½).—This patent relates to the securing of the clay portion of a glass feeder plunger to the operating rod.

The operating rod with its rack, 9, is securely fastened to the metal clamp, 10, into which the refractory stirrer, 11, fits. The operating rod and the upper portion of the refractory stirrer are hollow, and through them passes a metal rod, 14, with a head, 18, engaged by a threaded connection with the interior of the lower portion of the clay rod. Yielding contact between the end of the operating rod, 9, and the inner rod, 14, is provided by the spring, 16, which allows for any differential expansion of the iron and refractory material and avoids any loosening of the plunger. By holding the refractory material at these two points any tendency to break is reduced, and it is possible to continue using the intermediate portion of the plunger even when the latter breaks. S. E.

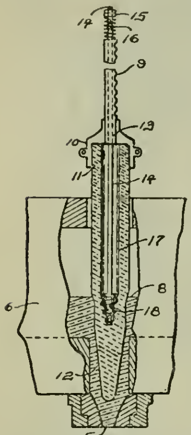


FIG. 165.

287. A Stopper for Flow-feeding Devices. V. MULHOLLAND, West Hartford, Conn., Assignor to HARTFORD-FAIRMONT Co., Canajoharie, N.Y. (U.S.A. Pat., No. **1421810**, July 4th, 1922. Filed July 26th, 1921, No. 487585).—The invention consists of a device for stopping the outlet of a flow-feeder in such a manner as to maintain the temperature of the outlet and thus prevent the delay, usually experienced on starting the feeder again, due to congelation of glass around the outlet. Fig. 166 shows the device applied to the Hartford-Fairmont feeder. A casing, 11, 12, is fitted around the end of the forehearth, 10, and is filled with non-conducting material, 13. A crossbar, 18, extends across the under-side of the casing, 11, and a lever, 23, is loosely pivoted on this crossbar. A cup, 22, is fixed to one end of the lever, and a weight, 25, is fixed to the other end. The cup contains non-conducting material, such as powdered kieselguhr, and the weight, 25, is sufficiently heavy to press the cup firmly against the outlet, 14, of the forehearth. The kieselguhr adapts itself to

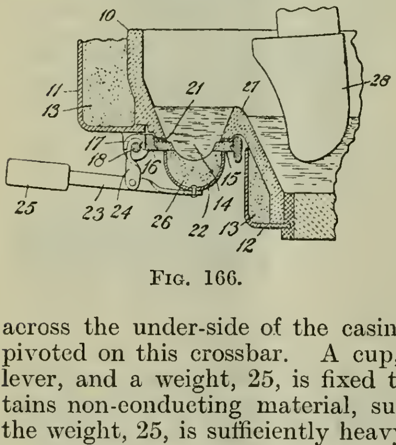


FIG. 166.

the shape of the glass within or beneath the outlet, and owing to its heat-insulating property, it prevents the glass in the outlet from freezing. Thus, when the cup is removed, the hot glass commences to flow at once and the time usually required to melt any glass frozen in the outlet is saved. G. D.

288. A Vacuum Capacity Device for Glass Machines. R. LA FRANCE, Toledo, Ohio, Assignor to OWENS BOTTLE Co., Toledo, Ohio (U.S.A. Pat., No. **1413742**, April 25th, 1922. Filed December 10th, 1920, No. 429637). In modern Owens machines which rotate with considerable rapidity and in which the gathering moulds are brought in quick succession into contact with the supply of molten glass and only remain in contact for a very short time, it is desirable that the full effect of the suction should be maintained at the gathering point so as to fill the moulds as quickly as possible. Any reduction in the vacuum at the gathering head due to the restricted passage ways through which the exhaust takes place is overcome by arranging capacity tanks adjacent to the gathering moulds and in communication with the main pipe through which the air is withdrawn. Fig. 167 shows such a tank, 22, surrounding the pipe, 11, the ends, 23, of the tank having air-tight connections with the pipe. Communication between the tank and the pipe is established by a number of perforations, 24, in the walls of the pipe. As there is no appreciable resistance to the passage of air from the mould, 6, to the tank, the full head of vacuum is maintained in the mould throughout the charging period, thus permitting rapid filling.

S. E.

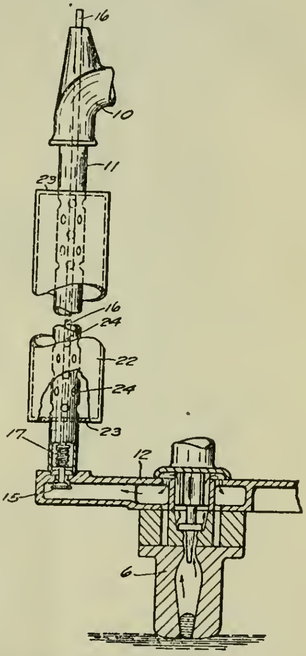


FIG. 167.

289. Metal or Alloy for Handling Molten Glass. PHILIPS' GLOWLAMPENFABRIEKEN, Eindhoven, Holland (Brit. Pat., No. **172610**, November 9th, 1921. Convention date, December 4th, 1920. Not yet accepted).—Apparatus for handling or working molten glass is made of a metal or alloy having a high melting point, not evolving gas when heated, and forming an adherent and insoluble coating of oxide which protects it from attack by the molten glass. Alloys of chromium or of aluminium with iron, cobalt, and nickel are mentioned. An alloy of 60 per cent. iron with 40 per cent. chromium in particular is suggested.

H. G. C.

290. A Mould Clamp for Glass-forming Machines. E. G. Bridges, Anderson, Indiana, Assignor to Lynch Glass Machinery Co., Anderson, Indiana (U.S.A. Pat., No. **1398670**, November 29th, 1921. Filed March 24th, 1920, No. 368208).—In order to ensure that the moulds on glass-working machines are completely closed and in their correct positions during the moulding or blowing processes, they are provided with lugs on their outer edges, and at each moulding position a clamping device is mounted in such a way that its jaws engage the lugs and firmly close the mould during the operation. In the present arrangement, the clamping device is supported on a bracket, which may be clamped at any suitable height. The jaws, 15, are pivotally and movably mounted on the ends of arms, 19, which are pivoted on the post, 17. The jaws have long operating arms, 22, which are connected through links, 23, to a cross-head, 24, carried on the extremity of the operating rod, 25. This operating rod is connected to a piston, 27, in the cylinder, 28, and is actuated at the proper times by the admittance of air into the cylinder through the pipe, 30, and under the control of valves operated in synchronism with the rotation of the machine. When air is admitted to the cylinder through the pipe, 30, the piston is moved towards the inner end carrying the cross-head with it. The springs, 20, carry the jaws up to the mould, and when forward movement is arrested the links, 23, swing outward and cause the jaws, 15, to clamp on the lugs, 14. S. E.

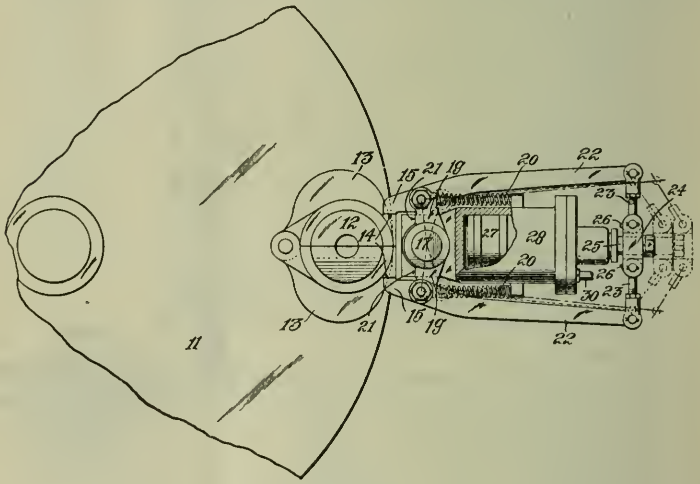


Fig. 168.

291. Air-cushioning Device for the Plunger of a Pressing Machine. W. J. Miller, Swissvale, Pa., U.S.A. (Brit. Pat., No. **174644**, September 24th, 1920. Convention date, October 16th, 1919. Not yet accepted).—Relates to pressing mechanism, particularly that forming part of a press-and-blow machine, and consists in providing an air-cushioning device for cushioning the movement of the plunger. In the machine shown in Fig. 169, a number of parison moulds, *H*, are mounted on an intermittingly rotated table, *E*. The charge, after it has been dropped into a mould, is pressed by a water-cooled plunger, *K*, the rod, 96, of which is fitted with a pneumatic cushioning-cylinder, 100, provided with an adjustable release valve, 122, by which the pressure of the plunger, *K*, may be varied. The rod, 96, is threaded, and a nut, 127, which makes contact with the cover, 101, of the cylinder, 100, allows the degree of cushioning to be adjusted. H. G. C.

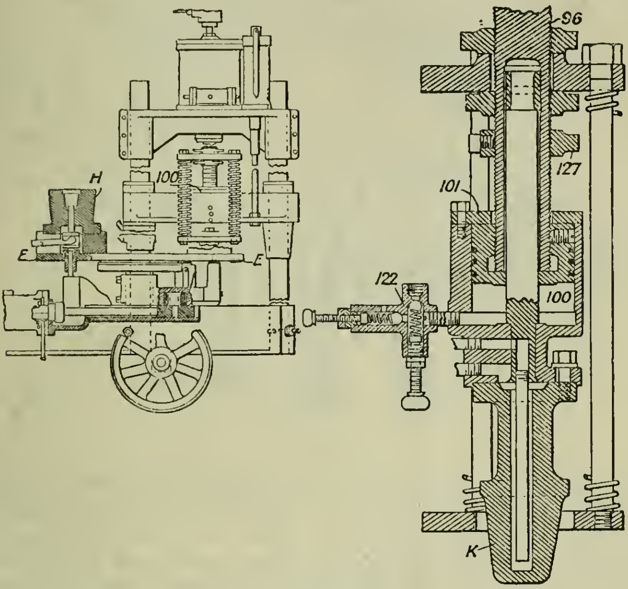


Fig. 169.

292. A Ring Mould for Glass Presses. P. Kucera, South Connellsville, Pa., Assignor to Capstan Glass Co., South Connellsville, Pa. (U.S.A. Pat., No. **1412358**, April 11th, 1922. Filed January 6th, 1920, No. 349704).—In order to prevent the edge of a ring mould wearing away and causing fins to be formed on pressed glassware, the ring mould itself is made of hardened metal which resists wear very much longer than softer metal. It is also claimed that such a hardened ring mould is better able to withstand the high temperature due to the hot glass. S. E.

293. A Mould-centring Device. O. H. Flint, Clarksburg, W. Va., Assignor to the Owens Bottle Co., Toledo, O. (U.S.A. Pat., No. **1399203**, December 6th, 1921. Filed January 7th, 1920, No. 349876).—The invention consists of a device for ensuring the exact registration of the mould cavities of a ring mould, 6, and a parison mould, 5, of an Owens machine, particularly moulds of the type in which several parisons are formed simultaneously, as shown. The ring mould is made in two parts, and the parison mould is also in two parts which close around the lower part of the ring mould. The centring device, which forms the invention, consists of a plate, 12, secured in a recess in one section of the ring mould and having a lug, 15, which engages in a recess formed in a section of the parison mould. Thus, when the sections of the parison mould close, the lug, 15, is engaged, and if any rotative displacement of the ring mould has occurred, the ring mould is forced into alignment and the mould cavities made to register correctly. G. D.

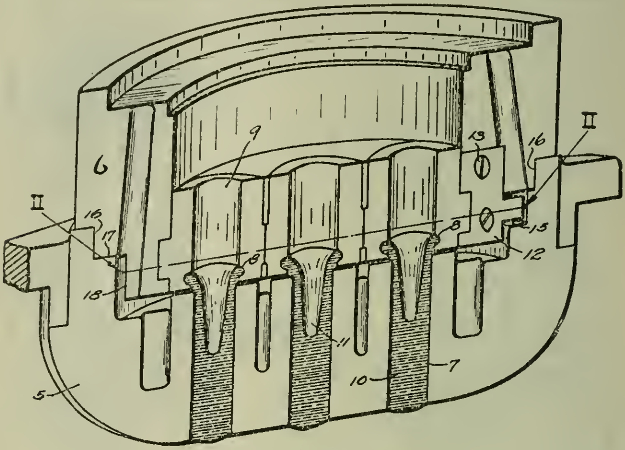


FIG. 170.

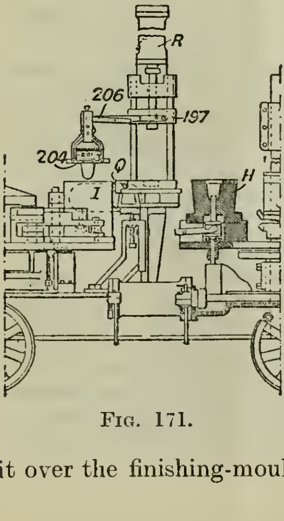


FIG. 171.

294. Transfer Mechanism for Automatic Machine. W. J. MILLER, Swissvale, Pa., U.S.A. (Brit. Pat., No. **174645**, September 24th, 1920. Convention date, October 16th, 1919. Not yet accepted).—A device for transferring the parisons to the finishing-moulds in a double-table automatic machine comprises coacting jaws for gripping a parison and means operated by fluid pressure for raising and lowering the jaws and moving them transversely. The transfer mechanism consists of a pair of jaws, 204, carried by an arm projecting from a slide, 197, which is raised and lowered by a pneumatic cylinder, *R*, and is swung round in a horizontal direction by a second cylinder, *Q*. The jaws descend on and grip the parison as it is raised out of the parison mould, *H*, lift it, and then swing it over the finishing-mould, *I*. The slide, 197, then descends and a lever, 206, striking a stop, opens the jaws and allows the parison to drop into the mould. The jaws, while still in the lowered position, are then swung back into position to grip another parison. H. G. C.

295. Machine for Making Vials. A. Meyer and H. Battistelli, Paris (Brit. Pat., No. **174049**, December 7th, 1921. Convention date, January 13th. Not yet accepted).—Relates to machines of the type in which short lengths of glass tubing are heated in the middle and separated to form small vials or the like. According to the invention, the tubular blanks are placed on an incline, 1, Fig. 172, and released singly by plates, 3, 4, which are raised alternately by a cam mechanism. The released blank rolls on to two sets of rollers, 8, mounted on carriages, 12, 13. Rollers, 27, then descend and hold the blank, 2, down on the rollers, 8, and a flame, 53, impinges on its centre. When the blank has softened sufficiently, the carriages, 12, 13, are separated by the action of cams, 18, 19, and the finished vials, etc., are released by the rollers, 27, and lifted off the rollers, 8, by pivoted fingers, 33.

H. G. C.

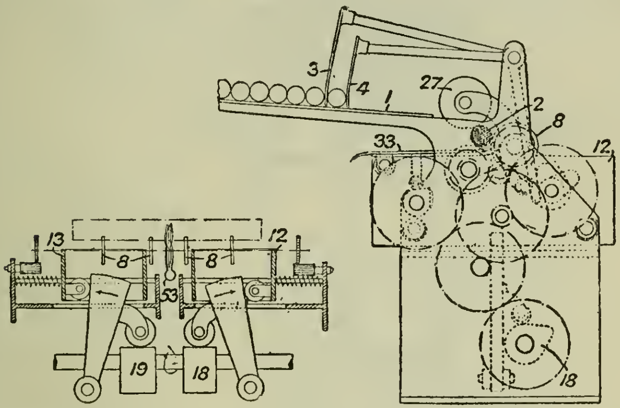


Fig. 172.

296. A Method for the Manufacture of Hollow Glass Bodies, Particularly for Electric Glowlamp Bulbs. E. Frank, Berlin, Assignor to Patent-Trenhandgesellschaft für Elektrische Glulampen, Berlin (U.S.A. Pat., No. **1420996**, June 27th, 1922. Filed September 3rd, 1921, No. 498484).—Opaque, white enamel is applied by a brush in a pasty condition to a part of a clear glass tube. To assist in drying it is advisable, although not always essential, to heat the tube to between 100° and 300°. When dry, a suitable length of this tube is heated up sufficiently to allow of a bulb being blown. The high temperature which is necessary for this operation is sufficient to effect an intimate union between the opaque and the clear glass, thus developing a reflecting opaque covering over a certain portion of the bulb. From a single glass tube a number of bulbs may be blown by painting the enamel paste along the tube at short intervals. S. E.

297. Drawing Glass Tubing or Rods. PHILIPS' GLOWLAMPENFABRIEKEN, Eindhoven, Holland (Brit. Pat., No. **172289**, November 9th, 1921. Convention date, December 2nd, 1920. Not yet accepted).—Relates to drawing glass tubing or rods continuously from a supply of the molten metal. According to the invention, the molten metal flows from a tank, 1, into an inclined rotating cylindrical chamber, *C*, which may be heated electrically or otherwise. It is drawn from the lower end, either by hand or mechanically, in the form of a tube, *T*, or of a rod, *R*. H. G. C.

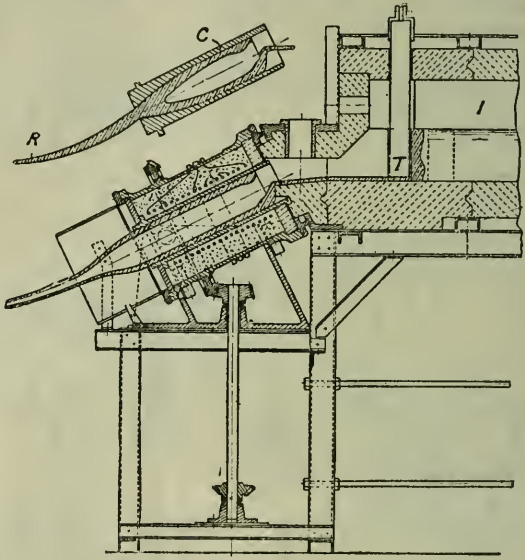


FIG. 173.

298. Process for Ladling Glass. H. F. HITNER, Wilkinsburg, Pa., Assignor to the PITTSBURGH PLATE GLASS CO. (U.S.A. Pat., No. **1342960**, June 8th, 1920. Filed June 30th, 1919, No. 307725).—The ladle employed consists of two jaws, 1 and 2, pivoted together and capable of opening 180°. These jaws are supported on a pipe, 3, through which passes a shaft, 4, and both

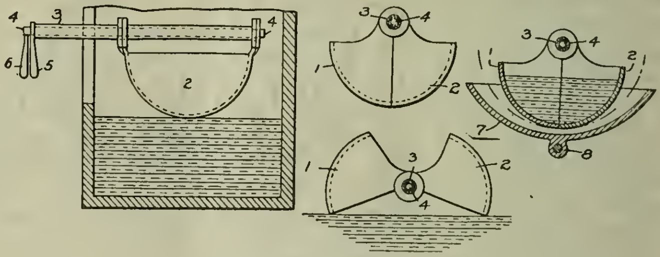


FIG. 174.

are provided with handles, 5 and 6. At the other end, section 1 is keyed on to the shaft, 4, while section 2 is keyed on to the pipe, 3. When it is desired to take up a ladleful of glass, the ladle is opened and brought immediately above the glass surface as shown. On closing the two sections a certain amount of glass is enclosed without causing much disturbance in the body of the glass. The ladle is used cold, so that chilled metal forms a skin adjacent to the metal sections and does not stick to them. On opening the sections to deliver the glass into the drawing pot, 7, this skin of chilled glass remains intact, thus preventing any flowing or mixing action which would set up cords and strings in the drawn glass sheet. After the drawing operation is completed, the pot, 7, is inverted and the chilled skin and waste glass drops out, thus avoiding the necessity of cleaning the pot by heating and scraping.

S. E.

299. Machine for Making Small Electric Lamp Bulbs from Tubing. BRITISH THOMSON-HOUSTON CO., LTD., London, and GENERAL ELECTRIC Co., Schenectady, New York, U.S.A. (Brit. Pat., No. **175440**, November 24th, 1920).—Relates to improvements in machines of the type described in Specification 14209/15 for making small electric lamp bulbs from glass tubing. According to the invention, the machine is provided with an inter-mittingly rotating frame, 15, carrying twelve chucks, 13, which hold lengths of glass tubing, 20, and rotate on their own axes. The frame, 15, halts twelve times during each revolution for an operation to be performed on each of the glass tubes, and, as a complete bulb is produced by six operations, two complete bulbs are produced every revolution. At station, *A*, Figs. 175 and 177, an annealing flame, 22, is directed on a complete bulb and a pointed flame, 21, on the neck. A gauge, 23, is raised to the

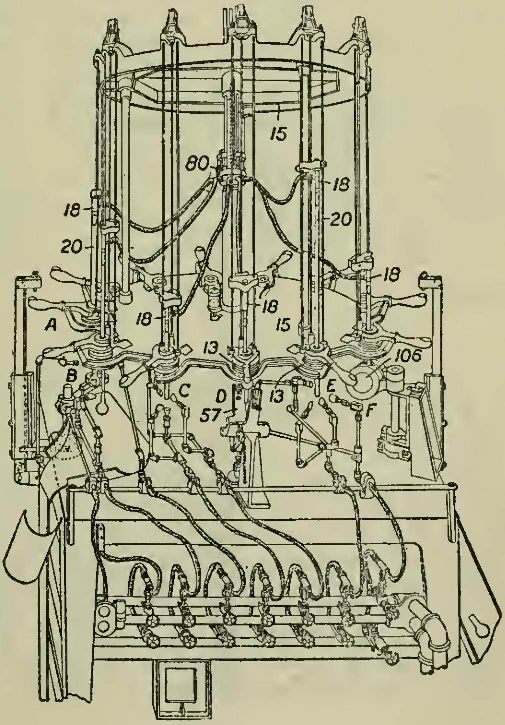


FIG. 175.

required height and the chuck is opened so as to drop the bulb on to the gauge, 23. The chuck is then closed, the gauge, 23, lowered, and the bulb moved to station, *B*, where the complete bulb is cut off by a flame, 51, and the tube, 20, is heated by a flame, 52. At station, *C*, the bottom of the tube is closed by a flame, 54, and the tube is heated up further by flames, 53. At station, *D*, Fig. 178, a small amount of air is admitted to the tube in a series of puffs to prevent its collapse and a two-part hinged mould, 57, is closed on it. One half of this mould is fitted with a neck-forming piece, 60, Figs. 176 and 178, and both halves are fitted with adjustable steadying-pieces, 61, to centre the tube. At station, *E*, the bottom of the tube is heated more intensely, and at station, *F*, the bulb is blown in a hinged mould, 106, by a series of air puffs. The air is controlled by a central valve system, 80, Fig. 175, having a vent which is normally open, but which is closed momentarily when a puff of air is required for blowing. A second finished bulb is produced simultaneously at the other six similarly equipped stations on the other side of the machine.

H. G. C.

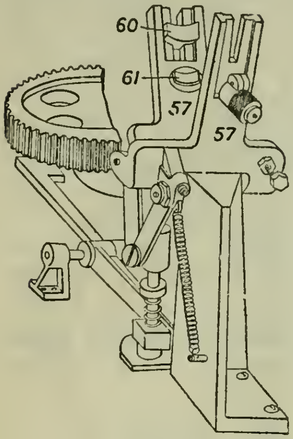


FIG. 176.

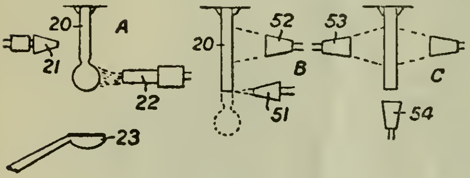


FIG. 177.

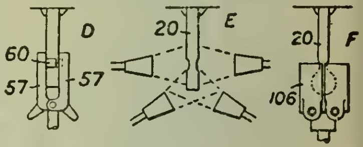


FIG. 178.

300. Compound Glass Sheets. J. Cox, London (Brit. Pat., No. **175044**, November 6th, 1920).—In making compound glass sheets, the surfaces are treated with a solution composed of gum mastic, amyl acetate, pyroxylin or collodion, and recinol oil, dissolved in absolute alcohol, and superposed sheets are subjected to pressure at a temperature which allows superfluous liquid to escape. When cool, the edges are treated with linseed oil, and the sheets are again heated and pressed; and the edges of the finished sheets are finally sealed with a solution of shellac in methylated spirit.

H. G. C.

301. Method and Apparatus for Making Sheet Glass. H. A. Myers, Toledo, Ohio, Assignor to the H. A. Myers Co., Toledo, Ohio (U.S.A. Pat., No. **1413766**, April 25th, 1922. Filed December 16th, 1918, No. 266855).—Glass is allowed to flow from a melting furnace under the control of a gate or valve. Forming rollers are situated below this orifice, the rollers being geared together by the spur gears, 6, and driven by any suitable means, so that the glass on emerging from the rollers does so as a uniform sheet. Knives are provided just below the rollers to cut the sheet of depending glass, after which the severed sections are fed on to an endless belt carrier which is provided with uprights to hold the sheets in an upright position. This conveyor delivers the sheets on to horizontal rollers.

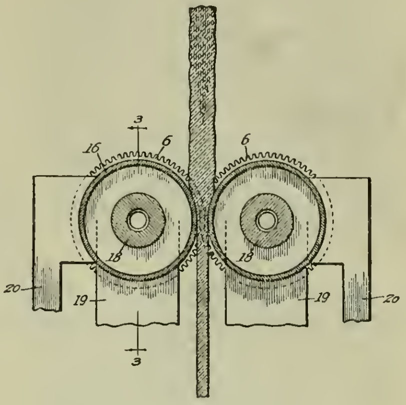


Fig. 179.

The forming rollers are made of some high-resistance metal such as nichrome and are heated to a temperature of about 900° so that the glass flows between the rollers in a fluid condition, whereby each roller is kept supplied with a coating of molten glass. In this way the sheet of glass does not come into direct contact with the rollers, but with the film or coating of glass on the rollers. Hence, the sheet is produced with a glazed or polished surface. For this purpose, the rollers are only rotated fast enough to keep them coated with molten glass. The rollers may be heated by any known or approved means. S. E.

302. Machine for Bevelling Sheet Glass. L. Kletz and B. Pearson, Manchester (Brit. Pat., No. **166231**, July 2nd, 1919).—A machine for bevelling sheet glass comprises an approximately horizontal and adjustable table, *e*, one or more grinding-heads, *s*, and a waste water trough, *b*. The glass, *a′*, is supported on a table, *e*, and the bevel is ground and polished by one or more rotary grinding-tools, *v*, supported on a slide bed, *d*, and traversed to and fro along the glass by a lead-screw, 4, the rotation of which is reversed or stopped by a clutch operated through a lever, 6, by a rod, 7, Fig. 186. The table, *e*, is pivoted, at *f*, to the framework of the machine and its inclination is adjusted by one or more screws, *g*, engaging threaded handwheels, *j*, supported by standards, *k*. The grinding tools are carried by shafts, *t*, mounted in heads, each head comprising a tubular boss, *s*, slidable on the bed, *d*, and the tools are fed towards the work by micrometer wheels, *w*; each head has a nut, 8, movable into and out of engagement with the lead-screw, by a handle, 9. A guard, *y*, is provided for each tool, and is lifted for inspection of the work, and again lowered, through links, 2, operated by a lever, 3; the guard is cut away to clear the glass. The glass is clamped to the table by a series of clamps, *o*, independently or collectively operable, through gearing, by a handwheel, *q*, Fig. 185. Water is supplied through pipes, 13, 14, from an overhead tank, and after use, passes to a trough, *b*; it is then filtered and returned to the overhead tank by a pump, 16. When more than one grinding-tool is employed, the first is set for a light cut, and the others for a following cut, so that the bevel may be completed in one traverse of the tools, or the last tool may polish the bevel after grinding by the others. The tools are driven from a shaft, 12. H. G. C.

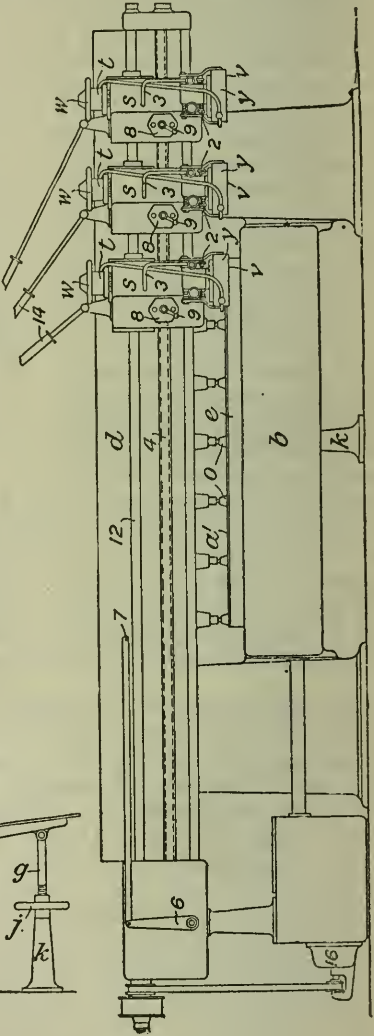


FIG. 186.

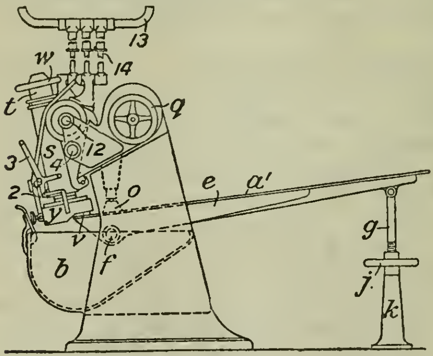


FIG. 185.

303. A New Bevelling Machine. E. KLIENS, London (Brit. Pat., No. **162216**, July 2nd, 1920).—A machine especially for bevelling the edges of circular or oval discs of glass, granite, hard-wood, etc., comprises an adjustable travelling work-holder which is propelled by its own driving-shaft towards the grinding-wheel and is automatically released and returned to the starting-point on completion of the grinding. The machine shown comprises a grindstone, *i*, on a headstock, *h*, and a work-holder, *f*, vertically and angularly adjustable on a pillar, *e*. The headstock, *h*, and the base, *d*, of the pillar, *e*, are mounted in guides, *c*, on the base, *b*, and are adjusted by screws, *l*, *k*. The work is placed on a vacuum plate, 48, attached to a variable chuck, shown also in Fig. 187, and is rotated by the main shaft, *o*, which is surmounted in bearings, *z*, 1, and is driven by a rope, etc., on a pulley, *x*, through worm-gearing, *t*, and toothed gearing, *q*, *p*. The bearings, *z*, 1, are parts of the work-holder, *f*, which is mounted in guides, *m*,

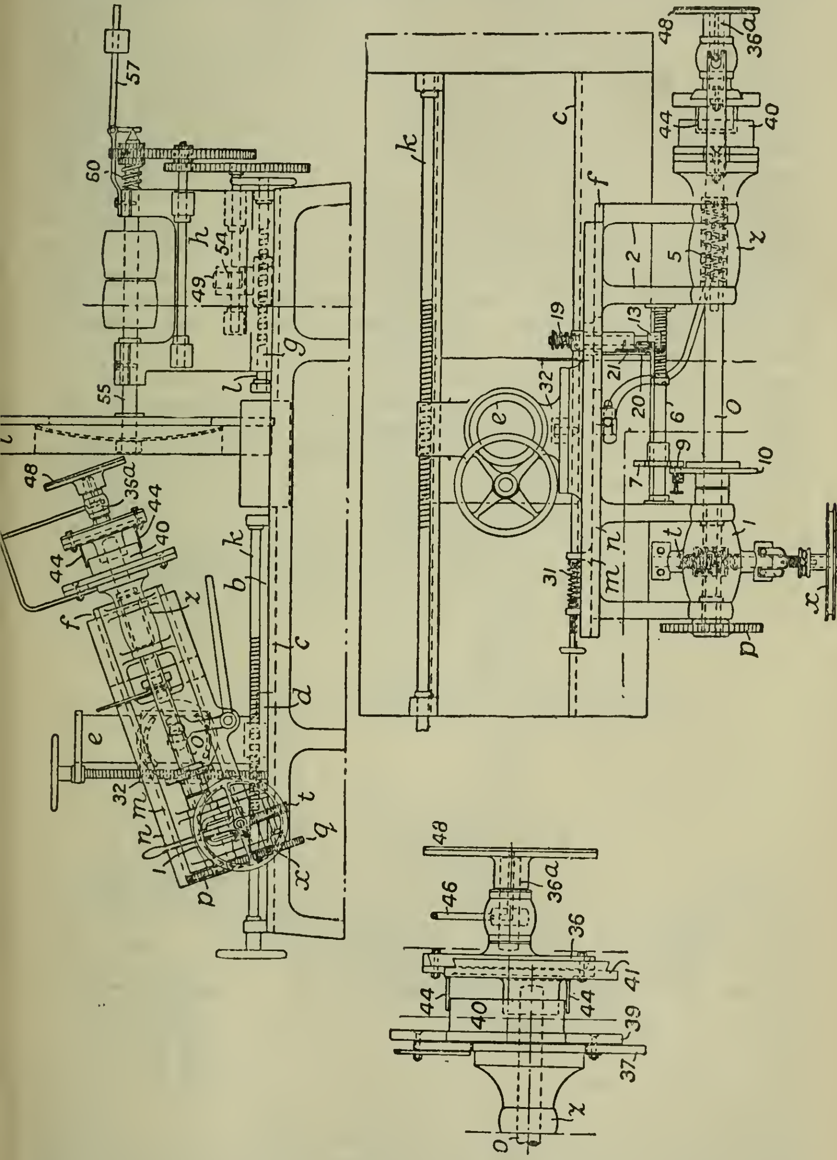


FIG. 187.

in a frame, *n*, pivotally mounted on a collar or sleeve, 32, on the pillar, *e*. The work-holder, *f*, is advanced by a spindle, 6, rotated intermittently by a pin, 9, on a wheel, 10, engaging with a star-wheel, 7, similar to a Maltese cross, the screwed part of the spindle, 6, engaging with a half-nut, 13, which is normally retracted by a spring, 19, but is brought forwards when necessary by a handle, 20, and retained in gear by a spring-pressed detent, 21, which is removed by a trip lever. The work-holder is moved forward until the bevelled collar, 2, on the spindle, 6, engages with the trip lever, when the spring, 19, withdraws the half-nut, and the spring, 31, retracts the work-holder. The chuck consists of a vacuum plate, 48, on a spindle, 36*a*, on a plate, 36, which is adjustably attached to a disc-shaped slide, 41, on the end of the main shaft, *o*. At the rear of the shoe, 41, are arms, 44, embracing the diameters of a circular ring, 40, on a plate, 39, adjustably attached to a plate, 37, on the end of the bearing, *z*. If the ring, 40, is set concentrically with the shaft, *o*, the vacuum plate rotates so as to grind circular discs; if it is set eccentrically, as shown, the machine grinds elliptical discs. The vacuum plate is connected by a pipe, 46, to a pump. The grinding-wheel is reciprocated in its own plane by means of an eccentric, 49, which bears against lugs, 54, inside the upper part of the headstock, *h*, and moves it on the lower part, *g*, which contains the adjusting-screen, *l*. The wheel spindle, 55, is pressed forward by a weighted lever, 57, a spring, 60, tending to retract it. The shaft, *o*, is divided within the bearing, *z*, and the parts are connected, for example, by a spigot and socket joint. A spring, 5, enables the upper end to yield when the grinding pressure is excessive. H. G. C.

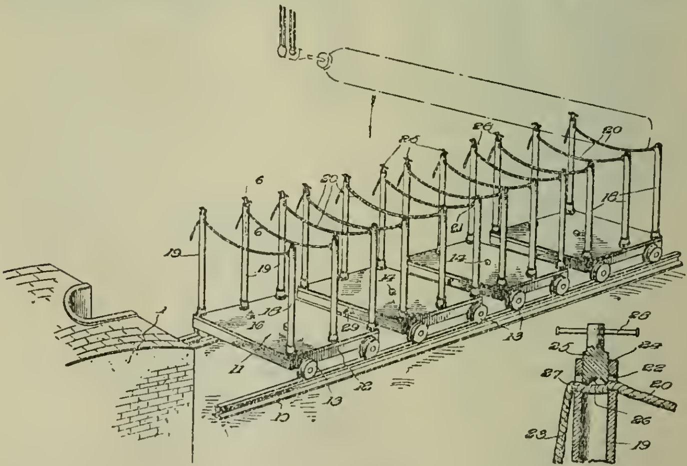


Fig. 184.

304. An Improved "Horse" for Glass Cylinders. E. G. Chase, Smethport, Pa. (U.S.A. Pat., No. **1414547**, May 2nd, 1922. Filed December 12th, 1919, No. 344381).—The invention consists of a "horse" for supporting glass cylinders after they have been drawn, and provides means for supporting the cylinder evenly at all points and means for facilitating splitting. The device comprises a number of trolleys, 12, coupled together and movable along rails, 10. A platform, 11, rotatably mounted on each trolley, has uprights, 18, 19, secured on opposite sides, the upper ends of opposite uprights being connected by ropes, 20, as shown. The ropes are secured to the uprights, 18, but are passed through holes in the uprights, 19, and clamped by bolts, 25. When a cylinder is laid on the horse, the clamps, 25, enable the ropes to be adjusted so that the cylinder is evenly supported along the whole of its length, irrespective of any irregularities. When the cylinder is capped and cracked up into sections, the rotatable platforms allow any section to be turned round into a position convenient for splitting. G. D.

305. New Process for Drawing Sheet Glass. J. P. Crowley and C. A. Rowley, Toledo, O., Assignors to the Libbey-Owens Sheet Glass Co., Toledo, O. (U.S.A. Pat., No. **1422036**, July 4th, 1922. Filed January 17th, 1921, No. 437660).—The invention relates to the method, often proposed, of forming sheet glass by forcing the metal through an aperture or slot of the width and thickness of the desired sheet. The method is impracticable as the sheets produced are marred and scratched by the walls of the aperture, and the aperture becomes choked by dog metal. According to the invention, these obstacles are overcome by causing the molten glass to flow through an aperture formed between moving surfaces coated with molten metal. In the apparatus, shown in cross-section in Fig. 180, glass from a tank, 1, flows over an inclined heated slab, 4, and falls in a thin stream, 5, into the space between metal rollers, 16, which are cooled internally and are rotated slowly in unison. The surface of the rollers is "tinned," and in order to prevent the surface of tin from melting or wearing away, the rollers dip into baths, 26, containing molten tin, or, if preferred, lead. The space between the rollers is adjustable according to the thickness of the sheet of glass to be produced. The glass collects between the rollers and flows down through the

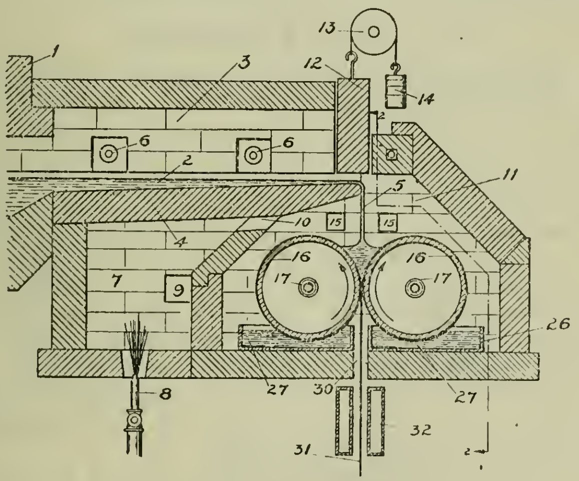


Fig. 180.

slot between them as a sheet, 30. The surface of tin prevents the marring of the sheet of glass and the slow rotation of the rollers constantly presents a fresh surface of tin to form the sides of the slot. G. D.

306. A New Glass Cutter. H. A. Ryther, Montague, Mass., Assignor to Miller's Falls Company, Massachusetts (U.S.A. Pat., No. **1419310**, June 13th, 1922. Filed June 14th, 1921, No. 477452).—The invention relates to a glass cutter which includes a disc turret and a plurality of glass cutting wheels carried near the periphery of the disc. The turret is made of a relatively thick disc, the thickness corresponding with the distance between the jaws of the tool, so that by tightening a central screw the disc is clamped firmly in any position between the jaws. When the central screw is loosened the disc may be rotated so as to bring any desired cutting wheel into the operating position. S. E.

X.—Glass Accessories.

307. Tight Closures with Crown Seals. A. Wollin (*Glass Container*, 1922, **1**, No. 9, p. 8).—Tests were made on large numbers of bottles, a common grade of crown seal being used. A small quantity of dilute sulphuric acid, and the necessary quantity of bicarbonate of soda to generate 50 lb. pressure were introduced into the bottles, the volumes of which had been determined. The bottles were sealed immediately, and the bicarbonate, enclosed in paper, was unattacked until the bottles were shaken. After solution of the solid, the bottles were tested for leakage, at once, and after standing for a time. Further samples were inverted for definite times immediately on attainment of the pressure of the gas, then set upright, and tested for leakage at various intervals. It was found that inverting the bottles for only a very short period was sufficient to cause a film of liquid to fill minute openings, and prevent leakage of carbonated beverages. V. D.

308. Beauty in Perfume Containers. R. B. Farnum (*Glass Container*, 1922, **1**, No. 10, p. 11).—The author discussed the suitability of containers made of metal, glass, and cardboard from the point of view of grace of line, of form, and of colour. Illustrations of both good and poor bottle forms, and of adaptations of labels were given. V. D.

XI.—General.

309. German Society of Glass Technology. (*Sprechsaal*, 1922, **55**, 333).—The formation of a new society with the title "Deutsche Glastechnische Gesellschaft (D. G. G.)," and with headquarters at Frankfort-on-Maine was announced. The objectives of the society were stated to be the promotion of research and the improvement of methods in glass technology, with a furthering of the teaching in high schools and training schools. It was intended to hold return meetings at which scientific-technical papers would be given, whilst technical literature and journals were to be promoted. A. C.

Reviews.

Annual Reports of the Society of Chemical Industry on the Progress of Applied Chemistry. Vol. VI. 1921. 625 pp. Price to members of the Society of Chemical Industry, 7*s.* 6*d.*; to non-members, 12*s.* 6*d.* post free.

The present volume maintains fully the interest and utility of the previous issues and will prove of the greatest value in bringing in a concise form to the notice of those interested the work done and progress made during the year in the various spheres of Applied Chemistry.

Twenty-six separate reports are included, of chief interest to glass technologists being those on Glass, Refractory Materials, Gas, Ceramics, and Building Materials. The section on Glass (12 pages) deals with the melting and working of glass, its Physical Properties, Glass Furnaces, including calculations on the efficiency of a tank furnace heated by a steam-blown gas producer, Glass Machinery and Glass-making Processes, dealing chiefly with suggested advances in the direction of automatic feeding and manipulation of glass from small electric bulbs to plate and sheet glass.

The section on Refractory Materials (16 pages) deals with the subject under the separate sub-sections: General Properties, Silica Refractories (with a special note on the heating and cooling of silica crowns in glass furnaces), Fireclay Refractories (of particular interest being the question of ageing and the plasticity of fireclays), Basic Refractories, and Special Refractories.

The section on Analytical Methods has been omitted, presumably to avoid overlapping with the Chemical Society's Report.

No attempt is made to describe in detail any particular research, but full references are given so that original papers may be consulted when necessary.

The complete and concise summary of work done during the year will prove of very great interest and assistance, particularly to those technical chemists who have not the facilities for systematic study of the numerous journals dealing with subjects in which they are interested.

J. H. D.

Report of the Committee of the Privy Council for Scientific and Industrial Research for the year 1921–22. (London: H.M. STATIONERY OFFICE. 3*s.* net.)—The report is the seventh issued since the formation of the Committee, and runs into 123 pages, closely packed with information. It is not necessary at this stage of the Committee's work to apologise for its life, and the opening passages of the report are exceedingly interesting in revealing how the Geddes Committee could find no cause for reducing the expenditure of the Scientific and Industrial Department beyond the Department's own economies, and so, indirectly, recognised the need for and the value of the work being done.

But although we now regard the work of the Committee as a permanent asset in the reorganisation of the industries of this country, it is well that the mind should be confronted at intervals with a clear vision of the work which scientific effort has to carry through. In the words of the Report (p. 11), "The problem before the country, as we see it, is to provide a means which will enable its population of nearly 50,000,000 to live and prosper. It is well recognised that for four-fifths of their food, and for a great part of the necessary raw and semi-manufactured materials for industry, the people of these islands are dependent on supplies from overseas. These supplies can only be obtained if this country is able to carry on its exporting industries in future with greater efficiency than the rest of the world, for it is doubtful whether we can compete, either by lowering wages beyond the limits of our competitors, or by securing a much greater human effort than they. If these two avenues are closed, competition, in the end, is confined to greater efficiency resulting from scientific work; for, in the long run, our outstanding business skill and organisation could not make good a deficiency of production or an obvious inferiority in our goods. We consider that scientific and industrial research, along the lines which we have laid down, and on which we have been building during the past seven years, is an essential factor in the national effort on which the continued maintenance of our present population unquestionably depends."

The report gives an account of the manifold activities of the Committee which are in operation with a view to carrying out the aims indicated in the paragraph quoted. The work of the various Research Boards, Research Committees and Research Associations for the year are surveyed and the general progress made indicated. In addition, information is given about the grants made to research workers, students in training, and specially endowed institutions. Other sections deal with the developments and the organisation of research in the overseas dominions, lists of publications both by individuals in receipt of grants, and of general departmental publications. The whole report makes most interesting reading, and is well worth the study of every manufacturer who possesses even a grain of initiative and enterprise.

If there is one matter for regret which occurs to the reviewer in reading the report it is the indication that in the future grants to scientific societies for assisting in research purposes are likely to be restricted in the future. The tendency is, of course, to transfer such work to more definitely constituted Research Associations formed on lines indicated and approved by the Advisory Council. The reviewer has often wondered if a great deal of time and money might not have been saved by stimulating and enlarging the work previously undertaken by voluntary bodies connected with scientific societies. Much money is easily absorbed in creating and running new machinery, and the persons who constitute the new Committees are generally those who would be otherwise connected with the voluntary research bodies attached to the scientific societies. The Research Associations are likely to exercise a powerful influence on the progress of industry within a short space of years. None the less, there is ample room for the disinterested efforts of the scientific society, even if less highly organised. W. E. S. T.

I.—Glass-making Materials.

310. Preparation of Titanium Dioxide. E. E. Dutt and P. C. Dutt, Kensington, London (Brit. Pat., No. **181775**, February 18th, 1921).—Titanium dioxide is obtained from titaniferous bauxite by heating the finely powdered ore, preferably under a pressure of 3—4 atmospheres, with five parts of ammonium sulphate at a temperature of 350—400°. The iron and alumina present are converted into soluble double sulphates, with evolution of ammonia, the silica and titanium dioxide remaining unchanged. The product is treated with water, when the iron and aluminium salts pass into solution, and the titanium dioxide forms a fine suspension. Silica and decomposed ore are allowed to settle, and the suspension of titanium dioxide decanted off and filtered. Specification 15590/06 is referred to. H. G. C.

311. Bauxite and Aluminium in 1921. J. M. Hill (Washington: United States Geological Survey. 1922. 8 pp.). F. W. H.

312. Felspar in 1921. F. J. Katz (Washington: United States Geological Survey. 1922. 5 pp.).—The statistics of production of felspar in this report are presented in tabular form only for the mine and quarry output (crude felspar). F. W. H.

313. Potash in 1921. M. R. Nourse (Washington: United States Geological Survey. 1922. 13 pp.).—Perhaps the most vital development in 1921 in connection with a possibly permanent domestic potash industry was the discovery in western Texas of samples of salt containing unusual percentages of potash in the drillings from wells that were being sunk for oil. No production was reported from alunite, silicate rocks, kelp, or wool washings. The only companies which reported continuous operation of their potash plants throughout the year produced their material as a by-product in the manufacture of cement, steel, and alcohol. F. W. H.

314. Silica in 1921. L. M. Beach (Washington: United States Geological Survey, 1922. 2 pp.). F. W. H.

II.—Glass: Manufacture and Properties.

315. Moulding Glass Objects by Centrifugal Force. H. P. Amphlett and Hume Pipe and Concrete Construction Co., Ltd., Westminster, London (Brit. Pat., No. **176737**, October 30th, 1920).—Moulding by centrifugal force.—A hollow or perforated blank of vitreous material is brought to final form in one or more centrifugal containing moulds such as are described in Specification 176,058. As shown, the centrifugal mould, *a*, is conveniently supported and driven by wheels or rollers, *b*. It may be heated by a gas-burner, *c*, or by hot waste gases. Means may also be provided for cooling by air or by water. Gas may be admitted to shape or to compress the material before it hardens. Pipes having T-junctions are formed in the first mould with thickened portions, and after local heatings may be deformed into a branch of the desired dimensions, centrifugal mouldings being subsequently employed. Elbowed or bent pipes may also be similarly made and objects of multi-sided formation. Moulds of various internal forms with or without cutting edges or dividing members may also be employed. H. G. C.

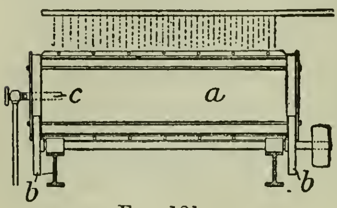


Fig. 181.

316. Method of Edge-fusing Ophthalmic Lens Blanks. A. J. Cross, New York, U.S.A. (U.S.A. Pat., No. **1432235**, October 17th, 1922. Filed June 28th, 1921, No. 480991).—One of the difficulties in fusing together portions of bifocal lenses is that whenever a polished surface of glass is submitted to too high a temperature it loses its brilliancy of polish, and in the new method, when fusing the edges of such blanks, the interior is shielded from the heat. When the parts are to be united, they are placed in position on a member, 10, which rests on a bed, 15, of refractory material, 15. The top concave surface is shaped to fit the outer convex surfaces of the members, 10 and 14, and is smoothly finished so as not to injure the lens blanks. An insulator, 16, is adapted to cover and overlap the hole, 11, in the member, 10. Similarly, the underside of the bed, 15, is insulated by the strip of material, 17. With the middle portions of the lens blanks, 10 and 13, thus insulated, perfect unions are obtained. S. E.

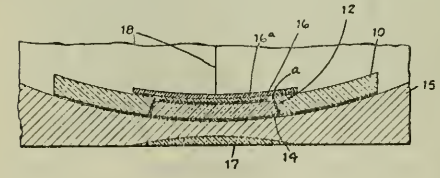


Fig. 182.

317. Manufacture of Glass Cylinders. H. P. Amphlett and Hume Pipe and Concrete Construction Co., Ltd., London (Brit. Pat., No. **176058**, October 30th, 1920).—Vitreous material, heated to a sufficiently fluid state, is wholly or in part shaped while being subjected in a mould to centrifugal force sufficient to effect expulsion from or rearrangement within the material of matter of different specific gravities, the material at the same time being freed from air bubbles. The operation is particularly adapted to the manufacture of plate glass formed of complete hollow cylinders, the surfaces of which may be polished during rotation. Arrangements may be made for admitting gases, such as steam or air, so as to compress the material before it finally hardens, and arrangements also for polishing or finishing the products while rotating at a convenient speed. The centrifugal force may be further employed for the positioning on the exterior of the finished article of elements of a strengthening or decorative character, or for facilitating the attachment of objects thereto. Metallic reinforcing wires may be incorporated with the material, which may consist of slag, sand, and caustic soda or other material. For a mould 12 inches in diameter, the speed may be about five hundred revolutions per minute. Fig. 183 shows a cylindrical mould, *a*, which is driven by frictional engagement with rollers, *b*, and which may be heated by a gas burner, *c*, or by other means. The mould is preferably formed in sections retained in position by end flanges or rings and longitudinal ties. Convenient end covers, a^3, Fig. 183, are provided, the cover having the packed extensions, a^4, rotating within the gas pipe, a^6. Means may be provided for cooling by air circulation or by a water service, *d*. For objects requiring a hard surface such as steps, the mould, within which is the cylindrical blank, is supplied with carborundum to form the outer surface of the blank. The blank, *k*, is then inserted in the rectangular mould, *l*, which is formed in two halves and is provided with cutting edges, *m*, *m′*, projecting into the mould to divide the hollow rectangle into two angle-shaped portions, k^1 and k^2, which are then employed as steps. H. G. C.

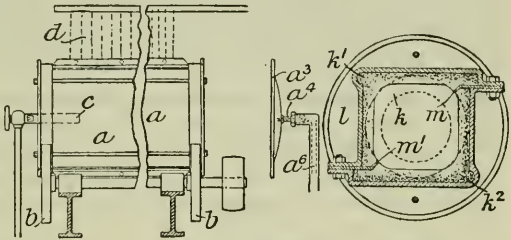


Fig. 183.

318. Process of Making Multifocal Lenses. E. D. Tillyer, Southbridge, Mass., U.S.A., Assignor to American Optical Co., Southbridge, Mass., U.S.A. (U.S.A. Pat., No. **1436217**, November 21st, 1922. Filed January 10th, 1921, No. 436121).—The formation of a bifocal lens from one piece of glass gives a very satisfactory lens, but the process is long and expensive. To retain the advantages of this type of lens and reduce the cost, the bifocal contemplated in this specification consists of two separate pieces of glass, preferably having the same coefficients of expansion and approximately equal indices of refraction. These two portions after being correctly ground and polished are fused together into one piece, the smaller lens lying on the surface of the major portion in the form of a thin wafer. S. E.

319. Making Corrugated Wire Glass. W. Cox and A. Shuman, Philadelphia, Pa., Assignors to the Pennsylvania Wire Glass Co. (U.S.A. Pat., No. **1418236**, May 30th, 1922. Filed December 14th, 1920, No. 430643).—The invention relates to a method of making corrugated wire glass and consists in rolling a flat sheet of glass with embedded wire netting having twists adapted when tightened to let out the strands between the twists, and then, while the sheet retains some of its initial heat, corrugating it by passing it between rolls having ribbed surfaces. G. D.

320. A Method of Making Varicoloured Glass Articles. F. M. Sigvart (U.S.A. Pat., No. **1372164**, March 22nd, 1921. Filed June 20th, 1919, No. 305655).—Relates to a process of making varicoloured ware, such as half opal globes and the like, and consists of a method of pressing a parison which is afterwards reheated and blown to shape. The mould, 5, Fig. 184, is fitted with a sleeve or liner, 8, which extends about half-way down the mould cavity and has a serrated lower edge, 8′. In the first part of the operation, a quantity of metal is placed in the mould and is pressed by a plunger, 11, which fits smoothly into the sleeve. The metal is thus pressed to fill the remaining space, and forms the lower section, *A*, of the parison. The plunger and sleeve are now withdrawn, more metal of a different colour is placed in the mould, and is pressed

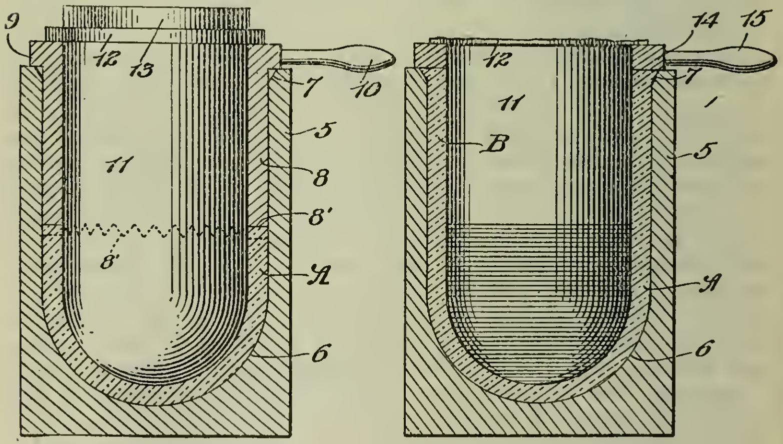


Fig. 184.

by the plunger, thus forcing it to fill the space, *B*, between the section *A* and a ring, 14, and to unite with the section *A*. The two-coloured parison is now removed from the mould, reheated, and blown to shape. G. D.

321. Vitreous "Jewels" for Bearings. T. G. McDougal, S. J. McDowell, and The Champion Ignition Co. (U.S.A. Pat., No. **1422216**, July 11th, 1922. Filed January 14th, 1920, No. 351438).—The invention relates to "jewel" bearings such as are used in speedometers and other instruments, and consists in forming compressed pellets of ceramic material which has a high viscosity when fused, and then heating the pellets to cause fusion without deformation.

A suitable composition consists of raw pulverised felspar mixed with a hardening material, preferably about 20 per cent. of clay. The mixture is fused to form a glass which is then ground to a very fine powder. After grinding, the powder is moistened with a solution of dextrin or other binding material, dried, screened, and then moulded in a press to the proper shapes. Finally, the shapes or pellets so formed are heated to such a temperature that they vitrify, and take a polish, but are not deformed. G. D.

322. Improvement in the Manufacture of Safety Glass. O. S. Marckworth (U.S.A. Pat., No. **1421974**, July 4th, 1922. Filed March 26th, 1919, No. 285348).—The specification discusses the defects of the present methods of making "safety" glass, in which a sheet of celluloid is cemented between two sheets of glass, and proposes an improvement. According to the invention, a solvent is applied to the sheets of glass and celluloid, the temperature at the time of application being such that the solvent is inactive, and then raising the temperature to render the solvent active.

The solvent preferred consists of a mixture containing 83·3 per cent. of fusel oil, 8·3 per cent. of methyl salicylate, and 8·3 per cent. of camphor. In use, the glass and celluloid are immersed in the solvent which is maintained at a temperature between 24° and 35°. The sheets are assembled, and after being removed from the solution are subjected to an increased temperature for a few seconds. Pressure is then applied and the temperature increased to render the solvent sufficiently active to cause the sheets to adhere to one another. After the welding operation is completed, the compound sheet may be immersed in a bath of linseed oil and a gum, such as kauri gum, which is maintained at an elevated temperature. This solution acts on the exposed edge of the celluloid to form a coating which prevents the article from disintegration by atmospheric action. G. D.

323. Glazes with Little or No Borax. Froelich (*Glashütte*, 1921, **51**, 420, 437, 451, 467).—Crystallised borax was added to glazes as a flux, and, further, in sheet ground glazes, as a purifier. Thus, surfaces glazes contained up to 22–24 per cent. of borax, ground glazes 32–34 per cent. In America, glazes of low boric acid content had been made, the borax substitute being a sodium–calcium–aluminium–fluorine derivative, probably "hot-cast porcelain" (cryolite glass), with 66·6 silica, 33·3 sodium–aluminium fluoride, or 70 silica, 19 soda, 11 alumina. The first borax substitutes in Germany during 1915–16 consisted chiefly of glass powder and opal glass powder 30—35 per cent., quartz 30, soda ash 35—40, or of glass with cryolite. Table I gives the composition of a series of borax-free sheet ground glazes and of some others low in borax content.

TABLE I

Constituent.									
Silica	54	52	51–53	48–49	49–50	50–52	53	58	60
Potassium oxide	5	5·5	—	3–5	3–4	5–6	3·5	4	—
Alumina	11·5	11·5	6–8	11–13	6–7	7–8	8·5	5	—
Sodium oxide	23	23	18–23	22–24	18–23	20–22	9	11	4
Boric oxide	—	3·5	—	—	(4)	—	—	—	4
Calcium fluoride	—	—	11–15	7·5–9	11–16	10–12	—	10	26
Calcium oxide	1·5	1·5	3–5	1–2	4–6	3–4	17	8	5
Sodium-aluminium fluoride	5	3	2–4	2–4	—	(3–4)	—	—	—
Magnesium oxide	—	—	—	—	—	—	4·5	—	—
Zinc oxide	—	—	—	—	—	—	1	—	—
Phosphoric acid	—	—	—	—	—	—	0·5	—	—
Sulphuric acid	—	—	0–1	0–0·5	—	—	—	—	—
Manganese oxide	—	—	—	—	—	—	2·5	2	—
Cobalt oxide	—	—	0–1	—	—	—	—	—	—

Analysis of the above compositions indicated in these glazes a normal alumina content of 6—8·5 per cent., an amount obtained by the admixture of 26—20 quartz and 24—36 felspar. Higher alumina content was obtained by the use of kaolin and clay. The 18—24 per cent. of sodium oxide was made up by the addition of 24—32 per cent. of soda ash. Fluorspar, 7—14 per cent., and calcium carbonate, 2—9 per cent., were also required. Finally, 1·5—4 per cent. of cryolite supplied the necessary portion of sodium–aluminium fluoride. The actual amounts of other substances used to replace 16 per cent. of boric oxide are given in Table II.

TABLE II.

Parts of Boric Oxide (12–16 *per cent.*) *Substitute.*

Boric oxide	4	4	4	4	—	—	—	—	—	—	—	—	0–4
Alumina	4	—	—	—	4	—	5	—	1	1	2	2	0–6
Sodium oxide	9	6	4	9	9	6	9	7	8	8	8	9	4–10
Calcium oxide	1	5	6	4	2	4	1	5	4	5	4	3	1–6
Calcium fluoride	—	7	10	5	—	7	2	8	6	—	4	6	1–10
Sodium-aluminium fluoride	3	—	—	—	5	3	3	—	—	4	2	—	0–4

The composition of a number of borax-free cast-ground frits without addition of millings is contained in Table III.

TABLE III.

Silica	56	58	66	68	75	75	76	76	72–80
Potassium oxide	5	5	5	4	4	4	—	4	4–8
Alumina	9	9	11	10	7	12	6	7	6–14
Sodium oxide	21	16	10	7	11	9	11	8	4–11
Boric oxide	—	4	—	5	—	—	—	—	—
Calcium fluoride	3	3	4	3	2	—	4	3	0–5
Calcium oxide	2	3	—	3	1	—	3	2	0–4
Sodium-aluminium fluoride	3	2	—	—	—	—	—	—	—
Calcium phosphate	—	—	4	—	—	—	—	(2)	0–4

A. C.

324. Titanium Glasses. H. WADE, London, and TITANIUM PIGMENT CO., INC., New York, U.S.A. (Brit. Pat., No. **176430**, October 29th, 1920).—Titanic oxide is introduced into glass batches in the ratio of not less than 25 per cent. of the whole. For example, silica 69 parts by weight, borax 10, sodium carbonate 29, lime 7, titanic oxide 45. H. G. C.

325. The Manufacture of Quartz Goods. W. SCHUEN (*Ker. Rundschau*, 1922, **44**, 457).—Pure quartz sand, quartzite or rock crystal was melted in an electric furnace and the molten material shaped by drawing, pressing, or blowing. If heated to a mobile state quartz or highly siliceous compounds volatilised rapidly, and hence absorbed much heat. Another difficulty arose in the working due to the fact that quartz had a small specific heat and a low heat conductivity, which caused layers and streaks owing to the surface setting too rapidly. Further difficulties arose since soft or liquid quartz was capable of dissolving almost any substance. Many substances—for example, silicon carbide—only dissolved in liquid quartz to be precipitated on cooling. In the manufacture of quartz goods in an electric furnace, silica was volatilised and reacted with the carbon resister, which was at about 2000°, with formation of silicon carbide and carbon monoxide. To minimise this reaction, pure carbon should be used; in particular the carbon should be free from sodium and potassium salts.

The author carried out a series of experimental meltings of a charge containing 23 kg. of sand, together with 20—100 gm. of oxides or sulphates of Al, Co, Ba, Sr, Sn, Zn, Fe, Cu, Co, Pb, P, Sb, or Cr, or, again, silicon carbide, sugar, and wood-charcoal. In no case did the oxides alloy themselves with the silica, and they were deposited on cooling giving a brittle product. All the sulphates were more capable of alloying, probably because they were all completely decomposed at the temperatures used. Hence they had no adverse effect on the fused quartz goods. Addition of iron in various forms gave truly characteristic results. Iron oxide gave a brown, friable, brittle, unusable product. Iron sulphate gave a green, very strong product. Iron filings gave a product containing many black specks but of good strength.

Silicon carbide, sugar, and charcoal in minute amounts gave a product containing bubbles throughout and quite unusable. Somewhat larger amounts gave a very frothy product resembling pumice-stone. The latter was crushed and remelted, but gave an unusable, "seedy" product.

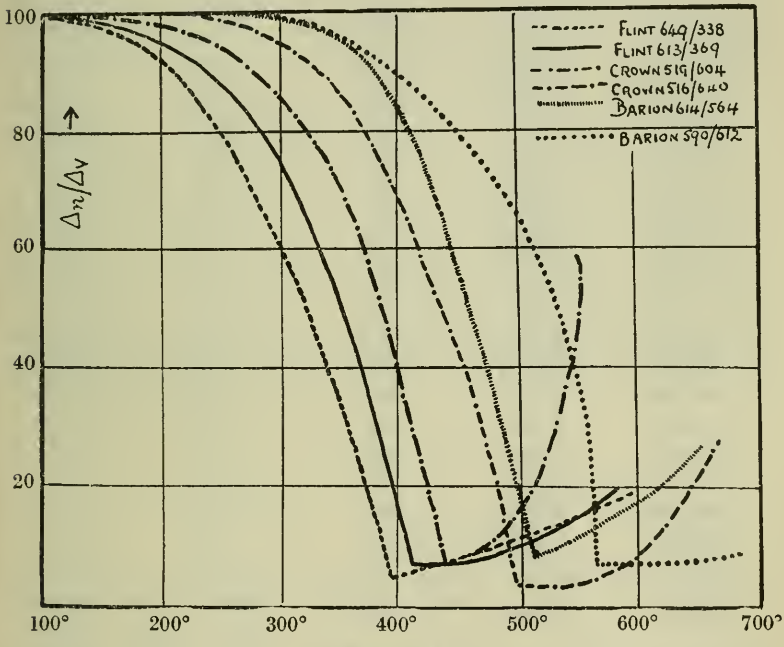
The best results were obtained with rock crystal from Norway and Switzerland. Sand containing minute white quartz fragments, in addition to clear grains, such as Dorrentruper sand, gave a bubbly product. Sand like Groskönigsforfer sand, which was washed in iron worm plants, from which the matted fragments and minute grains were washed out, gave almost clear products. which, however, contained very many black specks from iron derived from the washer. Quartzite was seldom pure enough, and, moreover, collected iron during its crushing.

The mother-of-pearl lustre on the surface of quartz goods was due to many extremely minute bubbles, derived from air absorbed on the sand grains or quartz fragments which could not escape from the viscous mass. Hence the more transparent the product the larger and the more crystalline the sand used. H. W. H.

326. Changing from Manganese to Selenium. J. E. ADAMS (*Glass Industry*, 1922, **3**, 219).—The author described the procedure to be followed in a 25-ton tank supplying glass to machines by an automatic feeder. He recommended making the change when starting up the tank afresh, so as to reduce the loss due to faults in colour. Proofs were taken at both ends of the tank, and if the colour in both was good the change over should be successful; if high at the working end and low at the dog-house, good glass could only be obtained by use of a high stack and a clean fire; if low at both ends, three or four days of green glass might be expected, and it was futile to add excess of decoloriser, which would give a yellow or brown cast for several days. The author's decoloriser consisted of powdered selenium, cobalt oxide, arsenic and pulverised limestone, such that 1½ lb. were required to decolorise the following batch: Sand 1000, soda ash 390, burnt lime 110, white arsenic 2, borax 2, cullet 3500 lb. Proofs were taken with a ladle at a constant depth in the dog-house just before filling-on, at a point cleared just inside the mantle block; they were examined for colour in a constant light, and after two or three days the manganese pink should be replaced by a selenium rose tint which it was fairly easy to keep when once determined. The product on the machines should still have a slight rose tint which, if the lehrs were not too hot or operated too slowly, should not alter.

The following comments were passed on the use of selenium: (1) Less decoloriser was required the hotter the tank and the greater the amount of glass withdrawn; (2) Selenium acted best under neutral or slightly oxidising conditions; (3) the use of nitre with selenium was against good theory and good practice; (4) foreign cullet of unknown origin might be used mixed with an equal amount of good cullet from the packing room, up to a total of four parts to five of batch. W. S.

327. The Annealing Temperature of Glass. F. Weidert and G. Berndt (*Zeitsch. tech. Physik*, 1920, **1**, 51; cp. this Journal, 1921, Abs. No. 103, and 1922, Abs. No. 191).—The first attempts to fix annealing temperature were, according to the authors, made by Schott, who observed a strongly strained cylinder of glass, with parallel ends, between crossed Nicols, and noted the change in the number of rings when the glass was heated over a period of twenty to twenty-four hours at a fixed temperature and again cooled. He wrongly concluded that the maximum annealing temperature for each glass was 465°, and the minimum temperature, below which the glass was completely hard, was 370°. Zschimmer, later, showed that these temperatures depended on the composition of the glass, the limits being 600° and 450°. Zschimmer and Schulz together, and Schulz alone, fixed the temperatures indirectly by heating a number of annealed pieces of glass to a series of fixed temperatures in an electric furnace until again free from strain and rapidly cooling them in the air. The difference of refractive index between the ordinary and extraordinary rays was then determined and taken as a measure of the strain. It was found that on heating beyond a certain temperature the two values showed no further divergence, and the results could be expressed in the form of a hyperbolic equation



Temperature.

Fig. 185.

$(T - T_0)\cdot(S + S_0) =$ constant, in which T_0 was that temperature at which the strain S was infinitely great (named by Schulz the "softening temperature").

Table I gives values of the softening point of a series of Jena glasses. The first column indicates the Sendlinger classification in which the first three figures denote the first decimals of the refractive index for the D-line and the second three the tenfold value of ν (that is, for glass 496/649 $N_D = 1{\cdot}496$, $\gamma = 64{\cdot}9$). The "softening temperature" had no physical meaning, since no glass could be infinitely strained. In practice, the temperature at which the strain no longer increased was of greater importance, corresponding with the point where the curve took a pronounced bend in a direction parallel to the temperature axis. The "softening temperature" was obtained by measuring the strains at a series of temperatures and, from the curve, calculating the required values T_0 and S_0 by the method of smallest squares.

TABLE I.

Design of glass.		A. Cohesion temp.	B. Softening temp.	A—B.
Sendlinger	Schott.			
496/649	O 802	603°	648°	− 45°
504/644	UV 3199	581	548	+ 33
516/640	O 3832	583	565	+ 18
516/692	S 367	509	530	− 21
518/590	O 203	555	647	− 92
519/604	O 3453	538	511	+ 27
523/513	O 3439	536	536	± 0
533/554	UV 3248	547	607	− 60
547/459	O 378	505	498	+ 7
565/554	O 463	632	640	− 8
573/575	O 211	632	639	− 7
577/414	O 340	484	499 485	− 15 − 1
580/538	O 722	632	642	− 10
583/464	O 78	578	611	− 33
590/612	O 2112	694	681	+ 13
609/589	O 2071	674	735	− 61
613/369	O 118	486	490 490	− 4 − 4
614/564	O 2994	686	681	+ 5
626/393	O 748	547	595	− 48
649/338	O 702	493	551 494	− 58 − 1
657/363	O 3269	530	568	− 38
717/295	O 41	465	473	− 8
798/265	O 198	457	469	− 12
917/214	O 386	425	526 557	− 101 − 32

A simpler constant to obtain was the "cohesion temperature," as defined by Zschimmer, namely, the lowest temperature at which two plane polished pieces of glass 2 mm. thick and 10 mm. in diameter coalesced when placed together. The cohesion temperature depended on various factors, such as the thickness of the plates and the duration of heating, whilst it assumed that no devitrification occurred on the heated surfaces. As an example of the time factor, Zschimmer found for crown glass O 3832:

Time of heating up .	1	20	50	110 min.	3	14	24 hours
Cohesion temp. . . .	611°	585°	574°	567°	564°	553°	540°

In three other glasses differences of temperature between the ten-minutes and thirty-minutes periods were 14·5°, 11·4°, and 4·9°. Constants were only obtained by extrapolating for heating times of zero or infinity, the former of which, for glass O 3832, was 615°. The value for an infinite heating period was termed the absolute value, identical with the annealing temperature. In practice, Zschimmer stated the value for thirty-minutes' heating, which on the whole lay near the softening temperature. The faults of the foregoing methods led the authors to devise the method of determining "deformation temperature." In this, a cube of 25 mm. edges was embedded with an angle in kieselguhr with a cube diagonal vertical. The cube was heated some two hours in an electric furnace up to a fixed temperature and held at this temperature for six hours. The lowest temperature at which an impression was so formed on the polished surfaces of the cube was found by a process of interpolation, and this was named the "deformation temperature." In general, the deformation temperature lay below the cohesion temperature (see Table II), whilst the value for cubes of 25 mm. edge were some 40° or 50° higher than for cubes of 50 or 75 mm. edge.

TABLE II.

Glass.				Differences.		
Sendlinger.	Schott.	Deform. temp.	Anneal. point.	Deform. temp.—Anneal. temp.	Soft temp. —Anneal. temp.	Cohesion temp.—Deform. temp.
496/644	O 802	570	—	—	—	+ 33°
516/640	O 3832	605	495	+ 110°	+ 70°	− 22
519/604	O 3453	520	430	+ 90	+ 81	+ 18
580/538	O 722	590	—	—	—	+ 42
590/612	O 2122	645	585	+ 60	+ 96	+ 49
609/589	O 2071	650	—	—	—	+ 24
613/369	O 118	460	410	+ 50	+ 80	+ 26
614/564	O 2994	645	565	+ 80	+ 116	+ 41
626/393	O 748	585	—	—	—	− 38
649/338	O 702	430	390	+ 40	+ 104	+ 63
657/363	O 3269	535	—	—	—	− 5

In the case of certain typical glasses, the deformation temperature was compared with the annealing temperature, as found by a modification of the Schulz method. In this method, the strain was measured at four points about 3 mm. from the corners of the cube face, and the sum of the largest and smallest values was taken (regardless of sign). The sum of the strains was denoted by Δ and expressed in units of the seventh decimal of the index of refraction. For the 50 mm. cubes a further series of four points, more remote from the corners of the cube was also taken. Two or three cubes of strained glass of each type were then heated at a series of similarly increasing temperatures, and cooled in a large furnace with automatic temperature control. The heating period for a temperature of 200° was about thirty hours; for 600°, about sixty hours.

TABLE III.

Relationship between Residual Strain $\left(100\ \frac{\Delta_n}{\Delta_v}\right)$ *and Temperature.*

		613/369				516/640				
	649/338		50 mm.		519/604		50 mm.		614/564	590/612
Temp.	25 mm.	25 mm.	*A*	*J*	25 mm.	25 mm.	*A*	*J*	25 mm.	25 mm.
201°	88·5	93·0	89·8	106·9	83·1	—	—	—	—	—
304	63·8	81·1	83·3	83·3	87·6	95·8	81·1	88·6	90·4	93·5
348	24·7	48·1	56·6	63·2	78·0	—	—	—	—	—
378	7·8	32·4	44·9	44·4	63·8	—	—	—	—	—
400	4·2	6·7	11·9	14·0	36·1	74·7	89·7	84·6	83·5	100·1
425	7·9	5·7	20·6	24·3	8·5	51·9	—	—	—	—
454	5·4	7·8	23·8	29·9	7·8	42·2	55·7	59·3	95·0	91·8
474	10·0	3·8	20·0	28·2	7·9	18·9	28·3	29·4	—	—
507	6·3	9·9	20·1	20·2	24·5	5·6	9·7	11·6	64·1	64·3
530	17·3	11·1	23·0	22·8	25·2	6·2	23·1	29·4	55·7	50·8
554	—	—	—	—	60·3	2·6	30·5	27·7	9·4	18·6
574	—	—	—	—	—	6·2	24·1	31·3	14·2	22·5
598	—	—	—	—	—	4·1	24·9	25·1	3·7	7·3
620	—	—	—	—	—	12·1	20·1	29·0	7·0	3·9
663	—	—	—	—	—	27·2	20·3	30·3	9·5	6·0
675	—	—	—	—	—	—	—	—	4·6	8·0

The strain of each cube before heating (Δ_v) and after heating (Δ_n) was found, and the value $100\ \frac{\Delta_n}{\Delta_v}$ calculated. For slow rates of cooling, it was found that the values for the inner points of the 50 mm. cubes (*J*, Table III) were practically equal to those for the outer points (*A*). The final strain was dependent on the temperature to which the cubes were heated, and was independent of the initial strain. When the temperatures were plotted against the strain ratio a series of similar curves was obtained, the break in each curve practically coinciding with the annealing point (Fig. 185).

Table IV gives a comparison of the annealing point so found with the deformation temperature, the latter showing a mean excess over the former of 70° (flint glasses 40° to 50°, others 60° to 110°). The variation of the residual strain with the rate of cooling is shown in Table V.

TABLE IV.

Glass.	Cube size.	Anneal. temp.	Deform. temp.
649/338	25 mm.	390°	430°
613/369	25 ,,	410	460
	50 ,, *A*	400	
	50 ,, *J*	405	(410)
519/604	25 ,,	430	520
516/640	25 ,,	495	605
	50 ,, *A*	500	
	50 ,, *J*	500	(565)
614/564	25 ,,	565	645
590/612	25 ,,	585	645

TABLE V.

Residual Strain in Cooling from the Annealing Temperature.

		Residual strain after cooling.	
Type of glass.	Size of cube.	Slowly.	Quickly.
613/369	25 mm.	4·5 per cent.	4·5 per cent.
	50 ,, *A*	2·5 ,,	12·0 ,,
	50 ,, *J*	4·5 ,,	15·0 ,,
516/640	25 ,,	3·5 ,,	4·0 ,,
	50 ,, *A*	4·0 ,,	15·0 ,,
	5 ,, *J*	2·5 ,,	20·0 ,,

A. C.

328. The Disintegration of Soda-Lime Glasses in Water. A. E. WILLIAMS (*J. Amer. Cer. Soc.*, 1922, **5**, 504).—Vessels made of soda-lime glass were treated in water at temperatures below boiling point, at boiling point, and up to 50 lb. pressure in an autoclave. The effects produced were illustrated by photographs.

Large battery jars were allowed to remain in water at about 60° for two months, the interior, however, containing no water. Cracking and spalling of two jars began after about two weeks, and the cracks grew larger continuously, whilst the spalled areas increased with time of immersion. A third jar of different composition and make, which was exposed to the same conditions, gave no evidence of cracking or spalling.

A tumbler boiled in water for six hours showed no sign of attack, but a similar one, after twelve hours boiling, showed signs of spalling and was cracked round the middle. Two other tumblers, made of glass containing only 5 per cent. of alkaline-earth oxides and less than 70 per cent. of silica were badly cracked and spalled. The disintegrating effect was cumulative in action, in that periodic boiling for short intervals showed very similar results to those obtained by a continued boiling for an equal length of time.

Milk bottles and tumblers were treated in an autoclave for periods of six hours at steam pressures varying from 5 to 50 lb. Whilst the effects of the treatments did not seem to increase in the same ratio as the pressures, the depth and area of spalling increased with the pressure or extended treatment. Six hours' treatment at 5 lb. pressure gave results equivalent to about twenty-four hours' continuous boiling at atmospheric pressure.

The spalling was confined to the outer surfaces in all cases. Grinding the edges of pieces of glass, before subjection to the action of superheated water and steam, resulted in greater attack. The interior surfaces of different articles were scratched and roughened by shaking with shot, carborundum, and water, after which spalling was observed on the interior of vessels on treatment in the autoclave, and this appeared, to the author, to indicate that the spalling on the exterior was due in part to a rougher surface than that of the interior. In order to make smooth the outer surfaces, a bottle and a tumbler were heated to softening point (515°) and then annealed. After treatment in the autoclave for six hours at 50 lb. pressure, these reheated articles were entirely free from spalling. Reheating and annealing below the softening point did not have the same effect.

An interesting test was made with two tumblers, one of which was reheated to softening point and then annealed again. They were subjected to a pressure of 25 lb. for six hours in the autoclave and then dried at about 250°. On the tumbler not reheated appeared an etched surface consisting of scale-like flakes of glassy material. These scales appeared as approximately parallel, curved lines which gave the appearance of flow lines of the glass in pressing or blowing.

The rate of disintegration, therefore, was stated to be dependent on time, temperature, and the composition and physical condition of the surface of the glass. The relative endurance of glasses might be studied, it was suggested, by the methods used, and standard tests based on them. F. W. H.

329. The Weathering of Glass Containers. K. L. Ford (*J. Amer. Cer. Soc.*, 1922, **5**, 837).—The frequently occurring cases of the deterioration of bottles and other containers in America when put in storage led the author to a study of the weathering process. Three classes of weathering were distinguished as the result of examining the surface of the glass microscopically. Class I, found when containers were stored for varying periods in warehouses subject to very wide and frequent changes in atmospheric conditions, was characterised by a heavy, white deposit; and coal-dust, dirt and other foreign matter were included in the deposit. Crystals deposited by the evaporation of the alkali solution of the glass were visible above the film. In Class II, a web formation of needle-like crystals of alkali salts was present, but no opaque film. Class III, which was the most common form in commercial glassware, was regarded as an early stage of Class I, having no continuous film.

The products of weathering were found to be crystals of a soluble salt, principally sodium carbonate, and an opaque film, the average percentage composition of which was SiO_2 66, CaO 7·5, Na_2O 14, CO_2 7·5, moisture, dirt, and organic matter 4. Packing in boxes which had been exposed to the weather and therefore contained moisture was very effective in inducing weathering, whilst the proper use of paper in packing decreased the tendency to weather.

Dipping in hydrochloric acid before packing also retarded weathering.

The paper was illustrated by a number of photomicrographs showing the types of weathering referred to. W. E. S. T.

330. Natural and Technical Constants of Glass. E. Zschimmer (*Zeitsch. Elektrochemie*, 1922, **28**, 194).—A theoretical paper not readily abstracted. W. S.

331. A Carbon Monoxide–Oxygen Cell with Glass as Electrolyte. Kallmann (*Zeitsch. Elektrochemie*, 1922, **28**, 81).—The *E.M.F.* of the reaction $2CO + O_2 \rightleftarrows 2CO_2$ with glass as electrolyte had been determined by Haber and Moser between 400° and 500°. The author had carried out work at higher pressures, using an adapted form of Haber's apparatus. The gas mixture to be examined was passed from a glass bulb container through a capillary to a longer glass tube into which it expanded and then passed out to a pump or manometer. The base of the tube was platinised inside and out and thus formed the electrolyte of the cell which contained a given gas inside, and also was surrounded by specified gases in turn.

Using a clean electrode (not used for CO/CO_2 mixtures), the potential difference for O_2 was soon constant; with a definite CO/CO_2 mixture a constant end value was soon reached, being different for different mixtures; on re-admitting the O_2, the end-point was more slowly attained, but the maximum rise on the first potential difference was 0·033 volt. With freshly platinised electrodes the potential difference should be steady within half an hour and remain so within $\frac{1}{2}$ millivolt for half an hour, and a CO/CO_2 mixture as inner electrode should show no considerable change. The following values were obtained :

Table I.

	Substance.	Percentage. Composition.	Measured p. d. volt.
1	CO/CO_2	8·27 CO	– 0·996
2	CO/CO_2	4·34 CO	– 0·977
3	O_2	95·00 O_2	– 0·048

Table II.

	Measured *E.M.F.*	Calc.
1—2	1·044	1·043
2—3	1·025	1·022

The values calculated were derived from the formula *E.M.F.* =

$$1{\cdot}118 - 0{\cdot}0707 \log \frac{pCO_2}{pCO \, . \, pO_2^{\frac{1}{2}}}.$$

W. S.

332. Variation in Refractive Index near the Surfaces of Glass Melts. F. TWYMAN and A. J. DALLADAY (*Trans. Optical Soc.*, 1922, **23**, 131).—A dense flint and a hard crown glass were examined. At about 1 mm. from the surface differences of refractive index of 2×10^{-5} and 1×10^{-5}, respectively, were found.

J. R. C.

333. Silicates of Strontium and Barium. P. ESKOLA (*Amer. J. Sci.*, 1922, **52**, 331).—Mixtures of the various oxides were prepared from pure quartz, specially pure calcium carbonate, barium carbonate, and strontium carbonate, and were melted, crushed, reheated, and ground twice before being employed in the determinations. Temperatures were read by a platinum–platinum-rhodium couple in conjunction with a potentiometer, the instrument having been checked against the melting point of diopside (1391·5) and anorthite. The refractive indices were determined by the method of Posnjak and Merwin (*J. Amer. Chem. Soc.*, 1922,

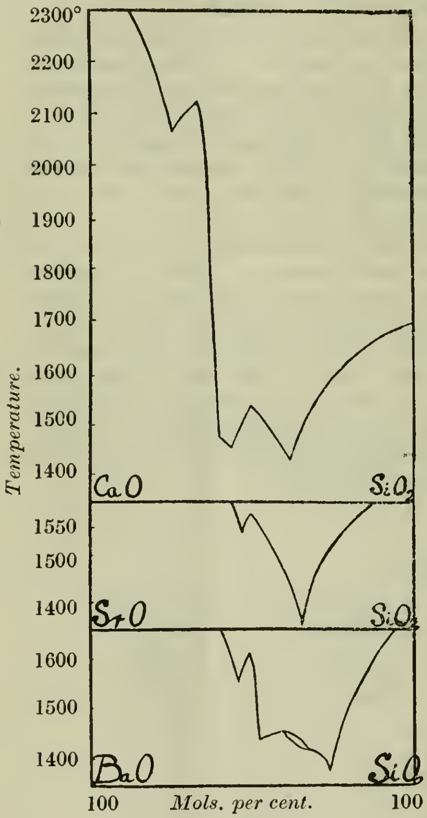


FIG. 186.

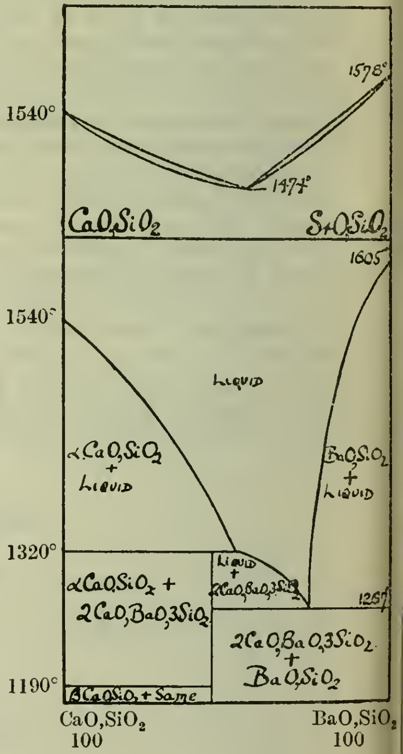


FIG. 187.

44, 1965). When the data for the systems SrO,SiO_2 and BaO,SiO_2 had been obtained, the author investigated the more complex systems CaO,SiO_2–BaO and CaO,SiO_2–SrO and attempted the formation of strontium and barium metasilicate compounds with magnesium metasilicate analogous to diopside, $CaO,MgO,2SiO_2$. Finally, the production of barium and strontium felspar was attempted.

Table I sets out the results of the experiments on the systems SiO_2–BaO and SiO_2–SrO, the corresponding data for SiO_2–CaO being included. The curves are shown in Fig. 186.

TABLE I.

Phase.	Molecular composition.		Temp.	Character of change.
	CaO.	SiO_2.		
Eutect. *cristob.*—α-CaO,SiO_2	37·0	63·0	1436°	Melt
α-CaO,SiO_2	48·2	51·8	1540	,,
Eut.—α-CaO,SiO_2–$3CaO,2SiO_2$	54·5	45·5	1455	,,
$3CaO,2SiO_2$	58·2	41·8	1475	Decomp.
Invariant pt.—$3CaO,2SiO_2$–$2CaO,SiO_2$.	55·5	—	1475	Melt
$2CaO,SiO_2$.	66·7	33·3	2130	,,
$3CaO,SiO_2$.	75·0	25·0	1900	Decomp.
Eut.—$2CaO,SiO_2$–CaO.	69·1	30·9	2065	Melt
CaO.	100·0	0·0	2570	,,
	SrO.	SiO_2.		
Eut. *tridymite*—SrO,SiO_2.	33·6	66·4	1358° ± 4	Melt
SrO,SiO.	50·0	50·0	1578	,,
Eut.—SrO,SiO_2–SrO,SiO_2.	52·5	47·5	1545	,,
$2SrO,SiO_2$.	66·7	33·3	—	—
Eut.—$2SrO,SiO_2$–SrO.	—	—	—	—
SrO.	100	—	—	—
	BaO.	SiO_2.		
Eut. *tridymite*—$BaO,2SiO_2$.	25·9	74·1	1374°	Melt
$BaO,2SiO_2$.	33·3	66·7	1420	,,
$2BaO,3SiO_2$.	40·0	60·0	1450	,,
Eut.—$2BaO,3SiO_2$–BaO,SiO_2.	47·8	52·2	1437	,,
BaO,SiO_2.	50·0	50·0	1604	,,
Eut.—BaO,SiO_2–$2BaO,SiO_2$.	53·5	46·5	1557	,,
$2BaO,SiO_2$.	66·7	33·3	—	—
Eut.—$2BaO,SiO_2$–BaO	—	—	—	—
BaO	100·0	—	—	—

The strontium metasilicate, SrO,SiO_2, could only be isolated in one form much like *pseudo-wollastonite*, all attempts to obtain another modification failed. The melting point was given as 1580 ± 4° (cf. Jaeger and van Klooster, 1578 ± 1), density at 30° as 3·650 (cf. J. and van K., 3·652 at 25·2°) and refractive index for the *D*-line as $\alpha = 1{\cdot}599$ $\gamma = 1{\cdot}637$. No trace could be found of the compound $3SrO,2SiO_2$. The melting point of the orthosilicate was far above the range of the platinum resistance furnace, and no farther modification of it could be found. Free SrO attacked the platinum, and if in excess of the amount corresponding with $2SrO,SiO_2$ did so in mixtures prepared from SrO and SiO_2. In the BaO,SiO_2 system, the barium disilicate, $BaO,2SiO_2$, was described and its characteristics were shown to be different from those described by Bowen (*J. Wash. Acad. Sci.*, 1918, **8**, 265; *J. Amer. Chem. Soc.*, 1919, **42**, 261). No evidence was obtained of the formation of solid solutions between $BaO,2SiO_2$ and SiO_2, but $2BaO,3SiO_2$ and $BaO,2SiO_2$ formed a complete series of solid solutions, the melting-point diagram being of Bakhuis Roozeboom's type I with no maximum or minimum. These were isomorphous and of orthorhombic symmetry, and their refractive indices showed a continuous but not linear variation with composition.

Fig. 187 gives the curves for the systems $CaO–SiO_2–SrO$ and CaO,SiO_2,BaO. The silicates of calcium and strontium formed a continuous series of solid solutions with a minimum at 1474 ± 3 corresponding with 56 per cent. SrO,SiO_2. The barium metasilicate was not isomorphous with strontium or calcium metasilicate, and with the latter formed no solid solutions. A double compound, $2CaO,BaO,3SiO_2$, was observed at 1320 ± 4, corresponding with 52 per cent. BaO,SiO_2. This melted to α-CaO,SiO_2 and liquid, and was optically unlike all the other metasilicates.

Both barium and strontium felspars analogous to *anorthite* were obtained by crystallisation from three times the amount of the corresponding vanadate, the latter being removed by washing with cold very dilute hydrochloric acid.

TABLE II.

System.	Wt. per cent.	n_D	Density (30°).
$SrO-SiO_2$.	SrO = 46·2	1·584	3·201
,,	= 50	1·5915	—
,,	= 60	1·624	—
,,	= 63·2	1·632	3·537
,,	= 67	1·644	—
$BaO–SiO_2$	BaO = 45	1·5665	—
,,	= 50	1·585	3·441
,,	= 56	1·6085	—
,,	= 65	1·645	—
$CaO,SiO_2–SrO,SiO_2$	CaO,SiO_2 = 100	1·628	—
,,	= 87·5	1·6265	—
,,	= 62·5	1·627	—
,,	= 43·7	1·628	—
,,	= 37·5	1·628	—
,,	= 0	1·632	—
$CaO,SiO_2–BaO,SiO_2$	CaO,SiO_2 = 100	1·628	—
,,	= 75	1·6345	—
,,	= 60	1·6395	—
,,	= 50	1·644	—
,,	= 40	1·649	—
,,	= 25	1·657	—
,,	= 0	(1·672)*	—

	$n_D\alpha$.	$n_D\beta$.	$n_D\lambda$.
Barium felspar	1·587	1·593	1·600
Cf. *celsian*	1·5855	1·5886	1·5941
Strontium felspar	1·574	1·582	1·5886
Cf. corresponding calcium compound	1·576	1·584	1·588

Attempts to obtain from magnesium metasilicate and barium or strontium metasilicate compounds analogous to diopside $CaO,MgO,2SiO_2$ were unsuccessful. This was regarded as a special case of the more common rule that in compounds in which calcium could be replaced by iron or magnesium, it could not be replaced by barium or strontium.

Table II gives some physical characteristics of some of the compounds described. M. P.

334. The Effect of Absorbed Gases on the Conductivity of Glass. V. Bush and L. H. Connell (*J. Franklin Inst.*, 1922, **194** (2), 230).—Langmuir had shown (*J. Amer. Chem. Soc.*, 1916, **38**, 2283) that the gas removed in a vacuum from glass was chiefly water vapour and that the amount so removed corresponded with a surface layer fifty-five molecules deep. Other investigators had confirmed this view (Dushman, *Review*, 1921, **24**, 246). The present work was undertaken to determine whether the penetration occurred throughout the mass of the glass. The specimens tested were tubes 10 cm. long, and 1·58 cm. internal and 1·87 external diameter. Electrodes, *C*, *D* (Fig. 188), were plated on externally and internally respectively, and the specimen enclosed in *B*, a vessel, which was

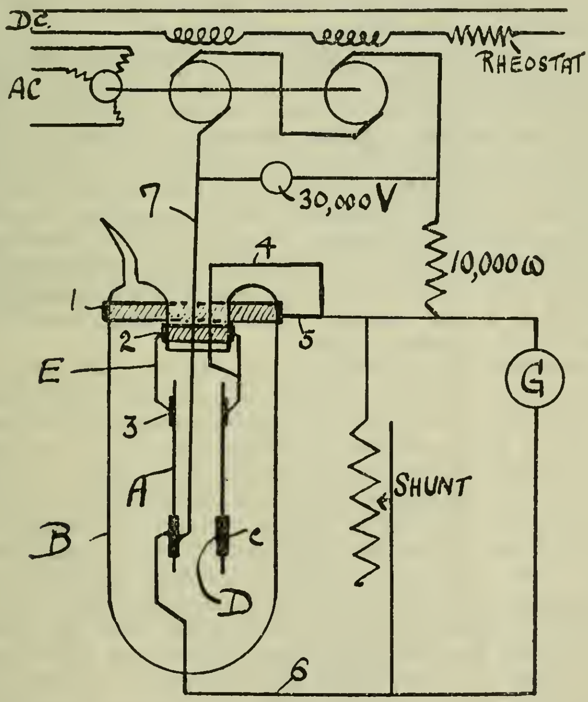


Fig. 188.

evacuated and sealed. Three guard rings, 1, 2, 3, served to protect the galvanometer. Two 15,000 volt D.C. generators coupled in series and run by a three-phase A.C. motor served to give a P.D. of 30,000 volts. This could be varied within limits by the rheostat operating in the circuit of the field coils. All parts of the apparatus at high potential were insulated by silk threads suspended from glass supports, and the insulation tested from time to time by breaking the connection at the outer electrode, taking the shunt off the galvanometer and applying the full voltage. A deflection of more than 3 mm. was taken as evidence of faulty insulation. The constant of the galvanometer with the shunt (10 : 1) had an average value $1{\cdot}722 \times 10^{-9}$ amp. per mm. deflection which did not vary sufficiently to warrant correction. The sample in its tube was immersed in an oil-bath at $25 \pm 0{\cdot}05°$ (the temp. coeff. of resistance at this temperature being 10^{10} ω per cm.^{3} per degree). The stray current error was reasonably small.

The actual procedure adopted in a determination was as follows. The specimen was washed in ether, dried in warm air, mounted in the outer tube, brought to constant temperature, and the resistance measured for various applied potential differences. The containing tube was then exhausted by a Langmuir pump, heated to 350° until no more gas was evolved, sealed off, cooled to the constant temperature, and the resistance again measured for the same range of potentials as before. The seal of the outer tube was then cracked slightly so that air entered slowly and further measurements were made to detect any error which might be due to gaseous conduction in a poor vacuum. Finally, readings were taken after the lapse of a few hours or days.

The measured volume resistivity of Corning G. 702 glass increased in the ratio 6 : 1 by the removal of the water vapour and other gases in a vacuum and even allowing for errors due to leakages, etc. The bulk of this increase was evidently due to the change in volume conductivity due to the removal of the gases. On exposure to air, this value slowly decreased but did not revert to its original value, the actual data being original resistance in ohms per cm.^{3} = 12×10^{10} after exhaustion = 69×10^{10}, three days after readmission of air = $35{\cdot}4 \times 10^{10}$, for a potential gradient of roughly 17,500 volts per cm. Pyrex glass, porcelain, and fused quartz tubes were similarly treated. The results from the last named were not quite accurate on account of the much higher resistivity to be measured. Apparently the resistivity of quartz did not decrease rapidly on exposure to air after vacuum treatment, since values obtained at intervals over two months always fell between those taken while exhausted on the one hand, and those taken a short time after admission of air on the other. The authors believed their results to show definitely that the whole mass of glass or quartz was permeated with gases and that the effect of this was to reduce the resistivity. By vacuum treatment a considerable dielectric loss was obtained, part of which was apparently permanent. Some penetration of the mass by gases did, however, occur at ordinary temperatures and pressures. M. P.

335. The Optical Constants of Selenium. L. P. SIEG (*J. Optical Soc. Amer.*, 1922, **6**, 448).—An isolated crystal was obtained and examined. Plane polarised light was reflected elliptically polarised from a face of the crystal, and the optical constants were calculated, using modifications of Drude's formulæ, from the form of the ellipse. In this paper, the experimental determination of the principal reflecting powers was described, and the results were compared with those previously obtained with cast selenium plates. Different values were obtained according to the orientation of the electric vector of the incident light. When this was parallel to the surface the reflecting power varied between 30 and 40 per cent. When the vector was perpendicular to the surface, it varied between 25 and 30 per cent. J. R. C.

336. The Optical Constants of Tellurium. G. D. VAN DYKE (*J. Optical Soc. Amer.*, 1922, **6**, 917).—Isolated crystals were used as in the preceding abstract. The crystal was shown to be doubly refracting. The indices of refraction were determined over the range 437 $\mu\mu$ to 650 $\mu\mu$. When they were plotted against the wave-length, parallel curves were obtained showing a minimum at about 460 $\mu\mu$ ($\mu = 2{\cdot}6$ and $2{\cdot}2$) and a maximum at about 550 $\mu\mu$ ($\mu = 3{\cdot}2$ and $2{\cdot}8$). The reflecting powers also showed minima and maxima in these positions, but the orientation of the electric vector had little effect. An average reflecting power of about 30 per cent. was found. Curves were also given showing the variations in the coefficients of absorption. J. R. C.

III.—Lamp-worked and General Scientific Apparatus.

337. Glass Pressure Gauge. S. KARRER, E. H. JOHNSTON, and O. R. WULF (*J. Ind. Eng. Chem.*, 1922, **14**, 1015).—The apparatus was designed to deal with gases which were corrosive towards ordinary gauge materials. The small tube, *F*, sealed through the main body of the gauge, *H*, has a thin diaphragm, *B*, blown on the end, separating the region, *D*, in which the pressure of corrosive gas is to be determined, from the region, *C*, which contains air, the pressure of which can be read by means of a suitable mercury manometer. The diaphragm is sensitive to differences in pressure between C and D, and a contact at A is provided to complete an electrical circuit containing a suitable indicator. The contact is adjustable through a side tube, K, shown in the side elevation of the apparatus, so that when the pressure in D is zero, a small pressure in C suffices to make contact. This small pressure is the zero correction to be deducted from subsequent readings to give the actual pressures.

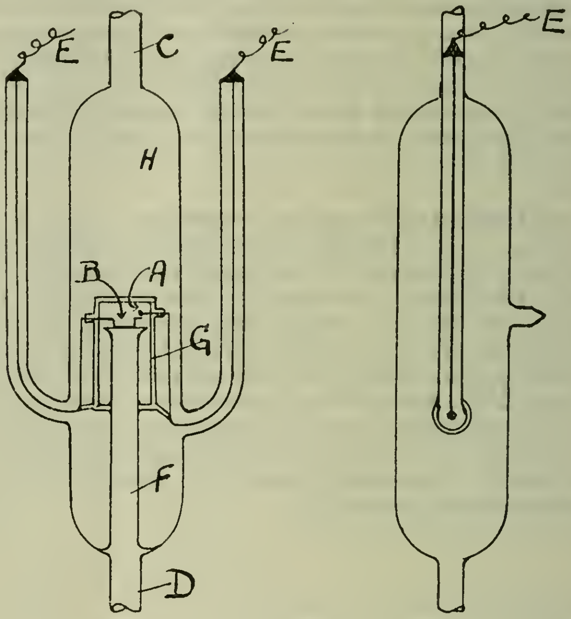


Fig. 189.

The sensitiveness of the contact was so great that diaphragms strong enough to withstand several atmospheres pressure could be used. The zero also consistently remained constant to a few tenths of a millimetre of mercury over long periods. In certain forms of apparatus an optical lever system was used in conjunction with the movement of the diaphragm to measure the pressures (cf. this Journal, 1921, **5**, 16, *A*). M. P.

IV.—Decorated Glass.

338. Glass Painting and Etching. L. Springer (*Glashütte*, 1922, **52**, 289, 305, 321, 337, 401, 417, 433, 449, 465, 481, 497, 513, 529, 545, 561, 577, 593, 609, 642).—Methods of preparing some of the colouring ingredients of enamels were described, and the proportions necessary to produce various colours (the latter as given by Hohlbaum, Strehblow, Hermann, and Randau). Fluxes for opaque coloured enamels were obtained by fusing together the ingredients : (1) 30 quartz sand, 80 red lead, or (2) 40 sand, 70 red lead, 20 borax. After being melted, the flux was poured into water, ground, and mixed with the colouring agent in the ratio of approximately 30 of flux to 1 of colouring agent.

For transparent enamels, a suitable flux was : 10 sand, 70 red lead, 20 boric acid; or, for purple colours, 10 sand, 80 red lead, 40 borax, and the colouring agent was added in some cases before, in others after, the fusion of the flux ingredients.

Surface colours (Schmelzfarben) were applied in thin layers upon opaque glasses and were similarly made by mixing a flux with a colouring agent, approximately in the proportion 5 or 6 to 1. A suitable flux in this case, except for purple colours, was made from 10 sand, 60 red lead, 3 boric acid. "Matt" colours were obtained by mixing "flat" colours with about 10 per cent. of stannic oxide or powdered porcelain.

A silver enamel consisted generally of very finely ground metallic silver (8 to 10 parts) or silver carbonate (10 to 12 parts) with lead borate (1 part) or basic bismuth nitrate, the so-called "bismuth oxide," as flux. Where the enamel was prepared from silver carbonate or from silver in the form of a pure fine dull-grey powder, it tended less to the production of a yellow tint on burning in than when used in the form of a leaf-like, glistening, crystalline powder. A silver sample obtained by precipitation from silver nitrate with copper gave good results only when washed perfectly free from copper salts. Substitution of basic bismuth nitrate as a flux, in place of lead borate, gave no special advantages, whilst bismuth borate was not suitable, since on burning in, even at lower temperatures, it gave a strong yellow colour and the silver adhered badly.

The following gold enamels gave good results : (1) 10 parts metallic gold powder, 3 red mercuric oxide, 1 lead borate; (2) 10 parts gold powder, 6 mercuric oxide, 1·3 lead borate; (3) 10 parts gold powder, 1 silver powder, 9 red mercuric oxide, 1·6 lead borate. Sometimes gold enamels were diluted with lampblack.

The following batches had been given at various times for producing glasses suitable for treatment with the "red etching" mixtures : *

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* Mixtures I–VI, see *Sprechsaal*, 1909; VII–IX, *ibid.*, 1910; X–XII, *ibid.*, 1913.

Batch material.	I.	II.	III.	IV.	V.	VI.
Sand	100	100	100	100	100	100
Limespar	12·5	13·0	11	15	30	12·5
Potash	29·0	12·5	20	30	30	25
Soda ash	12·5	25·0	14	—	—	8
Red lead	—	6	1	—	—	—
Borax	—	—	—	—	—	—
Potassium nitrate	—	4	1	—	—	—

Batch material.	VII.	VIII.	IX.	X.	XI.	XII.
Sand	100	100	100	100	100	100
Limespar	—	15	16	15	30	13
Potash	32	33	35	16	16	13
Soda ash	—	—	—	16	14	24
Red lead	60	10	—	—	—	6·5
Borax	4	—	—	—	—	—
Potassium nitrate	5	4	3	—	—	4

A suitable "red etch" for a glass made from the following batch, namely, sand 100, limespar 15, potash 30, was stated to be made by mixing 1 part of iron hammer scale, 3 parts copper hammer scale and ochre. For a hard glass (from 100 sand, 30 potash, 30 limespar) a good red etch was 1 part cuprous oxide, 4 parts pipeclay.

A red etch containing copper oxide marked the glass less at high temperatures than one containing copper sulphate, part of the etching action of the latter being due to the sulphuric acid vapour. For this reason, etches containing copper oxide needed a higher "burning in" temperature than sulphate etches. A series of tests was performed on various glasses with an etching mixture made from 100 gm. of ignited yellow ochre mixed with 200 gm. of crystallised copper sulphate. The copper compound was dissolved and intimately mixed with the finely ground earth, the mixture then being brought to dryness with constant stirring. After drying, the process was completed by heating to 300° and finally grinding to a fine powder. This etching agent was applied in the usual way with three burnings. A glass of the percentage composition SiO_2 72, CaO 9, Na_2O 5·5, K_2O 12 gave good results with a first burning at below 600°. Better still was the glass SiO_2 73·5, CaO 6·5, Al_2O_3 2, K_2O 18, a first burning-in being performed at 650—670°. A. C.

339. Iridescent and Interference Colours on Glass and Porcelain. (*Glashütte*, 1921, **51**, 516).—The formation of iridescent colours on glass beads and buttons was stated to have been brought about hitherto by means scarcely suitable for the least exacting needs. The products were "smoked" more often than not. A new apparatus was described which made possible the accurate mass production of iridescent beads of any desired colour or shade. The colouring fumes (vaporised metal salts) were produced in a chamber adjacent to the main muffle and were drawn in and discharged, after performing their function, into a flue leading straight to the stack, thus eliminating risk through noxious fumes reaching the worker. In the new types, which were self-acting, the beads after being fed into the container were moved successively through six chambers maintained at varying temperatures so graded that in the last chamber they attained their proper colour and were ready for withdrawal. M. P.

340. Device for Securing Glass Articles during Decorating. J. A. Milliken, Bayonne, N.J., U.S.A., Assignor to J. E. Marsden, Egg Harbor, N.J., U.S.A. (Brit. Pat., No. **178063**, August 25th, 1921. Convention date, April 8th. Not yet accepted).—A glass article which is to be decorated by cutting or grinding, is formed with an integral extension, *E*, coaxial with the body, *T*, of the article so that it can be gripped and rotated by a chuck, *C*. The chuck is secured to a rotatable hollow shaft, *S*, and has a pad, *a′*, of rubber to support the article, and a yielding member, *p*, against which a head, *B*, which is preferably formed on the extension, *E*, is clamped by hooked members, *j*, under the action of springs, *n*. The members, *j*, are pivoted on a bar, *h*, attached to a rod, *g*, which is free to slide in the interior of the shaft, *S*. When the rod, *g*, is forced inwards, by a lever, *y*, against the action of a spring, *v*, inclined faces, *s*, on the members, *j*, ride up on fixed pins, *r*, and release the bead, *B*, thus allowing the article to be removed. H. G. C.

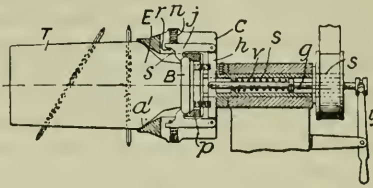

Fig. 190.

341. Abrasive Materials in 1921. L. M. Beach and A. T. Coons (Washington: United States Geological Survey. 1922. 4 pp.). F. W. H.

342. Mother-of-Pearl Imitation on Glass and Porcelain Ware. O. W. Parkert (*Sprechsaal*, 1922, **55**, 505).—Before treating the ware, it was necessary to clean the surface thoroughly and free it from grease and dust. In one method of producing a mother-of-pearl effect, a coating bath was prepared by softening gelatine in water, pouring off the latter, melting the gelatine on a water-bath, and then stirring in a thin aqueous cream of a mixture of zinc oxide, chalk, baryta, and white lead. The glass or porcelain was coated with this mixture and dipped into the least possible layer made by pouring a mixture of 1 part of nitrocellulose, 75 parts of alcohol (95 per cent.), and 20 parts of ether into water. The film, on drying, gave iridescent effects which were still more pronounced when benzine was added to the second bath.

In place of the nitrocellulose bath, there could be used one of 10 parts of potassium silicate, 90 parts of water with the addition of benzine. The effect was also obtained by first applying a gelatine solution in which ammonium bromide had been dissolved, drying, dipping the ware into silver nitrate solution, again drying, and finally coating with collodion solution. Gelatine could be replaced by clear resin varnish in the coating baths, but in such cases resin-soluble media were necessary in the baths for producing iridescence. In some cases, small amounts of an aniline colour capable of producing a metallic sheen (as fuchsine) were employed. A fine, mirror-like sheen was obtained by combining the effect obtained with fish-silver essence with the effect produced by adding a common salt solution to the gelatine, and, after drying, treating the coating with an aqueous solution of a thallium salt. A. C.

343. The Stamping of Ornamental Pieces of Glass. WILHELM HANNICH (*Ker. Rundschau*, 1922, **11**, 117).—The article referred to the decoration of glass by leaves and flowers in natural colours, or by lettering and reliefs, which were produced by stamping and subsequently fused upon a glass foundation. For the best results an easily fusible glass should be used. Moulds might be of iron or of bronze and should contain no overlapping engravings. In producing the foundation sheet, the mould was heated until it felt warm, was arranged horizontally and the liquid glass poured in to it from a ladle. To ensure that the glass penetrated and filled all the pattern-work, it was now rolled, the excess glass being stripped off from the edge. An iron plate was now laid on top, the whole inverted, and the mould removed. The glass plate so obtained was annealed.

When joining the ornamental piece of glass to the main piece, both were heated, and the former was laid on the latter. The ornamental piece adapted itself to the shape of the main piece and adhered to it. For stiff glass, or for special shapes, the adjustment was assisted by turning or light pressure.

Single pieces and letters were produced by machinery, for example, by the Sievert machine. A blank plate of glass was made by the usual rolling method of making plate glass. Whilst still hot, the plate was inserted into the stamping machine, in arrangement similar to a rolling mill. The "edge" or excess of glass could usually be removed by scissors or could be ground off. The front side of the piece of glass was generally curved and appeared brilliant. H. W. H.

344. The Importance of the Rickau (Photographic) Process for the Ceramic and the Glass Industry. JOSEF RIEDER (*Ker. Rundschau*, 1922, **11**, 117).—The article to be etched was covered with a material sensitive to light and containing caoutchouc and asphalt or other resins, then covered by a negative or a stencil, and exposed to light. A powder of wax and asphalt was scattered over it and adhered only to the unexposed portions. The exposed portion was removed by washing with a pad of cotton wool soaked with spirits. The dust and unexposed coating were then fused together by the application of heat.

To resist hydrofluoric acid, a specially robust covering must be left. Hence, before dusting, a specially prepared fatty dye was rolled over the whole surface. The dye only retained its colour on the unexposed portions. After heating, the dusting and heating were then repeated to give a sufficiently thick protective coating.

This process was particularly used for etching scales, but could also be used for mirrors of up to 2 m. in length. In the latter case, the heating was carried out with a fine pointed flame. A special case was that of thermometers. To allow for the variation in diameter of the capillary tube, a sufficiently large number of negatives were kept ready.

The author claimed that the process was much less costly than the printing method of producing scales.

The process was also applied to burned-in figures on opal glass or white flashed glass or enamel. It could be used for glass painting if multicoloured " outline " designs only were used. Regarding hollow-ware, the method could be used if the article was only curved one way when a film negative could be used, as, for example, when putting the advertisement mark on a beer glass. A half-tone process was being elaborated. The method could also be used instead of the " low-pressure " process in which steel and copper engravings were used to print on tissue paper.

The whole of the research work involved had been carried out by a photographic chemical works in Charlottenburg. H. W. H.

V.—Optics and Optical Instruments.

345. **The Crossing of Rays Produced by the Refraction of a Prism.** A. Whitwell (*Optician*, 1922, **63**, 399).—If a ray of white light be incident on a prism surface between the normal at the point of incidence and the apex of the prism, the dispersed red and violet rays would cross after emerging from the prism, provided that they emerged at all and were not totally reflected at the second face. It was shown that for the phenomenon to be observed, very large prism faces would have to be used, and this was held to account for the absence of any record of experimental detection. J. R. C.

346. **An Improved Refractograph.** A. Whitwell (*Optician*, 1922, **63**, 359).—This instrument, designed to facilitate the drawing of refracted rays, consisted of an **L**-shaped piece of celluloid, with sides of the up-stroke suitably graduated. The manner of use was described and the accuracy of the results obtainable discussed. It was concluded that drawings accurate to 1/3° could be made. J. R. C.

347. **The Best Form of Spectacle Lenses.** A. Whitwell (*Optician*, 1922, **63**, 331).—A continuation of previous papers dealing with this subject. The effect of decentring the lenses on the curvature of the field was examined for a pair of convexo-plane lenses. J. R. C.

348. **The Effective Power of an Ophthalmic Lens.** C. Sheard (*Optician*, 1922, **64**, 227).—It was shown that a biconvex and a biconcave lens of equal curvatures and hence equal powers

could not neutralise each other, but must form a meniscus lens. This was because the lenses were not infinitely thin. The shape and thickness of a lens were important factors affecting the determination of the power of a lens. The effective power was defined as the power which was determined as the reciprocal of the distance from the ocular surface to the ocular focal point. The neutralising power referred to the other surface, and the difference between the two was illustrated by examples. J. R. C.

349. Effects of Changes of Surface Curvature at the Focus of an Astronomical Object Glass. E. W. Taylor (*Trans. Optical Soc.*, 1922, **23**, 241).—In the construction of a large doublet the polishing tools might have radii of curvature slightly different from those theoretically required if the finished objective was to be completely corrected for spherical aberration and the *C*- and *F*-rays brought to a common focus. The author considered the following procedure as the best to re-establish the corrections, provided that a small alteration of focal length was immaterial. (1) Make the third surface (the first of the negative lens) as perfect as possible. (2) Alter the radius of the fourth surface until the whole objective is corrected for colour and a perfect figure is obtained. (3) Correct for spherical aberration approximately by altering the second surface of the positive component, as a smaller alteration is required on this surface than on any other. (4) Complete this correction by alteration to the first surface. (5) Repeat operation (2). The first, second, and fourth surfaces would not be accurately spherical, but this was immaterial if the aperture ratios were less than *F*/10. The procedure was illustrated by reference to a doublet constructed of known glasses. J. R. C.

350. A Physical Study of Spherical Aberration. L. C. Martin (*Trans. Optical Soc.*, 1922, **23**, 63).—Analytical expressions for the intensity of light near the focus of a lens system were, the author stated, usually too complex for satisfactory physical interpretation and, after a preliminary theoretical consideration of the aberrations, he proceeded to study them experimentally. In the theoretical part of the paper, the aberrations were expressed in terms of phase differences, thus enabling a clearer physical conception of their effects to be formed. When the performance of an optical instrument was investigated practically it was frequently found to be better than the calculated aberrations indicated. This was due to the distribution of light in the image not being taken into account. In his study, therefore, the author employed an extremely small pinhole as the object, in order to eliminate this effect. The aberrations of a known microscope objective were computed for varying tube-lengths and checked by an adaptation of the Hartmann method. The appearances at and near the focus with differing known aberration residuals were photographed and examined for size and light distribution. Spherical aberration was found to produce marked asymmetry on each side of the focus.
J. R. C.

351. The Changes in Aberrations when the Object and Stop are Moved. T. Smith ((*Trans. Optical Soc.*, 1922, **23**, 311).—A mathematical discussion of these changes in the case of a centred optical system. The formulæ obtained could be used to determine the effect of small changes in a system, such as the variation of a thickness, provided the aberrations of the original system were known. J. R. C.

352. Achromatism with One Glass. T. Smith and L. M. Gillman (*Trans. Optical Soc.*, 1922, **23**, 328).—It was shown that in systems composed of thin lenses of the same kind of glass, and achromatised by selecting suitable positions for the components, the object and its image could not be simultaneously real. J. R. C.

353. The Optical Three-apertures Problem. T. Smith (*Trans. Optical Soc.*, 1922, **23**, 132).—The space within which the optical elements of an instrument must be confined was usually specified. At the same time, the minimum number of lenses must be used. The paper proposed a method of dealing with the problem. J. R. C.

354. A Special System almost Mathematically Free from Defects in the Image. M. Lange (*Optician*, 1922, **64**, 61).—By means of a simple mathematical calculation, it was shown to be possible to construct a cemented doublet which acted as a telescope, free from spherical and chromatic aberration, coma, and astigmatism. The magnification would be so small, however, that such a system would be of no practical use. J. R. C.

355. Achromatic One-radius Doublet Eyepieces. J. W. Gifford (*Trans. Optical Soc.*, 1922, **23**, 99).—A note on the performances of eyepieces of the Huygens and Ramsden types constructed from pairs of such doublets (see this Journal, Abs., 1921, **5**, 21). Such eyepieces were adapted both for the telescope and for the microscope. By their use a more perfect achromatism and a flat field were obtained. J. R. C.

356. Theory of Toric Spectacle Lenses. A. Gleichen (*Optician*, 1922, **64**, 267).—An analytical discussion of the refraction of a converging beam by means of toric lenses with parallel axes of rotation. In this first part of the paper the geometry of toric surfaces was dealt with. The paper was too mathematical for compression into an abstract. J. R. C.

357. The Classification of Optical Instruments. T. Smith (*Trans. Optical Soc.*, 1922, **23**, 323).—Exception was taken to the classification of optical instruments by the signs of their powers, that is, as positive or negative combinations, and a more fundamental division into five classes, based upon the separation of the four Gaussian constants into two groups, was proposed. J. R. C.

358. The Mechanical Construction of the Microscope from a Historical Standpoint. A. Pollard (*Trans. Optical Soc.*, 1922, **23**, 334).—Although the simple lens was known to the ancients, there was much doubt as to whom belonged the credit of inventing the microscope. It was claimed for Galileo, Drebbel, Fontana, and Borellus, all about A.D. 1600. The construction was improved by Monconys, who was the first to use a field lens in 1660, by Hooke, by Newton, who designed a reflection microscope, and by Leeuwenhoek. Marshall invented a "double microscope" in 1693 and Bonani described a compound microscope in 1698. The author described the development, thenceforward, of the instrument, special attention being directed to the improvement in focussing devices. The paper referred especially to instruments in the South Kensington Museum. J. R. C.

359. The Newtonian and Aplanatic Telescopes. H. Chrétien (*Revue d'Optique*, 1922, **1**, 13, 49).—A comparison of these two types of telescopes and their advantages and disadvantages. J. R. C.

360. A Projective Treatment of the Submarine Periscope. T. Smith (*Trans. Optical Soc.*, 1922, **23**, 217).—A method of investigating the general features of a periscope by homocentric projection was described. The paper cannot be compressed into abstract form. J. R. C.

361. Angle Comparators of High Precision for the Goniometry of Prisms. J. Guild (*Trans. Optical Soc.*, 1922, **23**, 297).—Two applications of the method of substitution were described. In the first, which yielded results accurate to one or two seconds, the angle was compared with a standard of the same nominal value. Two telescopes were set to receive light from a collimator reflected from the faces containing the standard angle; the unknown angle was substituted and the difference between the two measured by the readjustment of the telescopes which was necessary. This method had the advantage over the ordinary method in that imperfect collimation was immaterial. An improved comparator required a special variable prism of small angle which was placed between the telescope objective and its focal plane. By varying the deviation produced by the prism, minute changes in the direction of the incident light could be measured. An accuracy of 0·1 second was obtainable when the angle of a prism was measured by a method involving this principle. J. R. C.

362. The Design of Diaphragms. C. F. Smith (*Optician*, 1922, **64**, 223).—The author clearly described, with the help of diagrams, the principles of the use of diaphragms, leading up to the design of the three employed in the construction of a telescope. J. R. C.

363. Systems for Reading Small Mirror Deflections. G. W. Moffitt (*J. Optical Soc. Amer.*, 1922, **6**, 494).—Only those systems suitable for use with instruments having plane mirrors were considered. The use of an ordinary small telescope involved a restrictive field of view, due either to mirror limitations or to field limitations. The latter could be removed by proper design; the former could not be eliminated if small mirrors were used. By the use of a special objective mounted on the instrument, near the mirror, in combination with a scale and an ocular on the scale support these limitations could be removed, and it was possible at the same time to maintain the focus and freedom from parallax for large deflections. J. R. C.

364. A Non-polarising Spectrophotometer. A. J. BULL (*Trans. Optical Soc.*, 1922, **23**, 197).—The body, the selective absorption of which was to be examined, was placed in front of the lower half of the slit of a constant deviation spectroscope, the eyepiece of which was replaced by a second, compound slit. Two beams of monochromatic light were thus obtained. A split lens formed two images of the prism face, one illuminated by unabsorbed light, the other by light which had passed through the body under examination. The images were brought into juxtaposition by a rhomb and examined through an eyepiece. The intensity of the unabsorbed beam could be decreased by partly closing half of the compound slit, until equality was obtained. The extent to which this slit was closed formed a measure of the absorption of the particular wave-length employed. J. R. C.

365. Medical Optical Instruments in Reinforced Glass. (*Revue d'Optique*, 1922, **1**, 35).—A description of spectacles for myopes, hypermetropes, and astigmatic persons, made of glass strengthened on the "triplex" principle. The weight of such glasses was about 3 gm. more than those made in the usual way. Telescope lenses could also be made on this principle. J. R. C.

366. The Photometry of Optical Instruments. J. GUILD (*Trans. Optical Soc.*, 1922, **23**, 205).—A modification of the Wanner optical pyrometer was used for this purpose. The results obtained agreed with those given by rotating sectors and other similar methods and also with the theoretical values obtained by taking into consideration the number of glass-air surfaces. J. R. C.

367. Polariscopes : A Few Typical Forms of Early Instruments. F. J. CHESHIRE (*Trans. Optical Soc.*, 1922, **23**, 246).—A description of some instruments in the South Kensington Museum. The development of polariscopes was traced from the discovery by Malus in 1808 of polarisation by reflection to the modern petrological microscope. In the earliest forms the polariser was a glass plate and the analyser either a glass plate or a single crystal. The invention by Nicol, in 1828, of the Nicol prism greatly improved the apparatus and was to be found in all the instruments made by Nörrenberg, who was responsible for marked advances. The substitution of the analysing glass plate by a Nicol prism and improvements in the optical system and facilities for centring were the chief points about the remaining instruments. J. R. C.

VI.—Illumination and Illuminating Ware.

368. Leading-in Wire Assembly for Vacuum Tubes. S. Thronsen, Chicago, Illinois, U.S.A., Assignor to Western Electric Company, New York, U.S.A. (U.S.A. Pat., No. **1432926**, October 24th, 1922. Filed October 22nd, 1919, No. 332444). — A flanged glass stem, *A*, Fig. 191, is placed on the platform, 2, and clamped in position by the jaws, 12, which are pivoted at 24 and pass through slots, 5, in the fixed plate, 4. The glass tube is held in line with the opening, 6, of the main stem, by the guide, 7. The wires, *C*, cut to length, are dropped through the glass stem, *A*, and are inserted into each of the perforations, 8, in the guide, 7, which supports them upright and parallel in proper spaced relationship. The lower ends of the wires rest on the block, 9, and the extent to which they project from the stem is thereby determined. The upper end of the stem, *B*, is heated, and, when soft, is pressed around the wires as shown.

S. E.

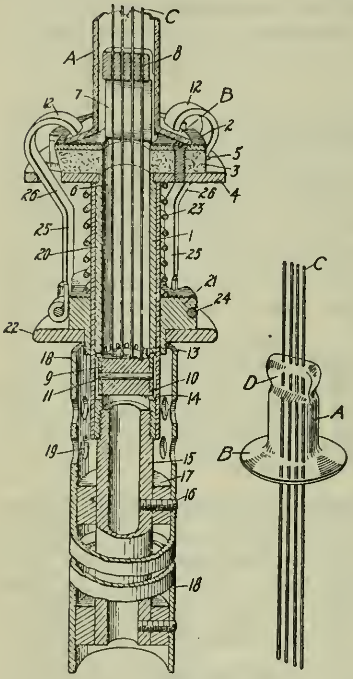

Fig. 191.

369. Manufacturing Self-luminous Devices. R. W. Erdle and The Cold Light Manufacturing Co. (U.S.A. Pat., No. **1410741**, March 28th, 1922. Filed May 16th, 1918, No. 234849).—Small self-luminous elements are made by sealing a radioactive mixture, such as is used on the hands of watches, in sections of glass tubing. The elements are used in devices for indicating the position of articles in the dark.

G. D.

370. Motor Headlights. (*Trans. Optical Soc.*, 1922, **23**, 256).—A series of papers on this subject. J. W. T. W. Walsh critically reviewed the problem and showed that the requirements of the driver and other road users were mutually antagonistic. In order to detect an inconspicuously dressed pedestrian at 100 ft. from the headlights, an effective candle power in the beam of 3000 candles was found to be necessary. If such a beam was seen directly by an observer glare must be produced, for glare occurred at 500 candles. The only effective devices, therefore, were those which restricted the beam so that it was not viewed directly. The legislative enactments of various countries were considered. They differed widely, but mostly agreed that the intensity of the beam at a certain height above the ground should be below the glare limit. This rendered the efficient observation of signposts and road signs impossible, and, in addition, was almost impossible of attainment in practice because of the convexity or concavity of road surfaces, and because of the large variations in the intensity of the beam at a given height which were produced by small variations in the loading of the car. A bibliography of the work done on the subject was appended.

H. Grubb described the C.A.V. Non-dazzle Headlight. This was designed to conform to the regulations of the State of Massachusetts, which were the most stringent enacted. A paraboloidal, or ellipsoidal, mirror projected the light from an electric lamp through a diaphragm with three openings on to a moulded lens. This consisted of ten lenses in three tiers, the component lenses being so arranged that in the part of the field required to be brightest there were ten overlapping images.

H. S. Ryland considered the causes of glare, and stated his opinion of the requirements to be fulfilled in the design of a headlamp. Two lamps satisfying these requirements were described. In both cases, a hemispherical and a section of an ellipsoidal mirror were used to collect the light from the source on to a projection lens. In one, an auxiliary condensing lens also contributed to this end.

F. Meyer entered a plea for brilliant headlights and against restrictions, arguing that the motorist with a good field of view would see the other road user, and, provided the latter did not jump about, would avoid an accident. In towns a dimmed light should be compulsory. He described the Zeiss headlight, for use with acetylene lamps. The light was transformed into a parallel beam by a paraboloidal reflector, the "forward" light being reflected back on to the paraboloid by a section of a spherical mirror, the source being at the centre of this section. The parallel light was slightly scattered to the sides and downward by glass fronts with prismatic ribbing. By using a shallow form of reflector it was possible to make it of glass instead of metal. The life of a silvered glass reflector was longer than that of any other kind.

E. Culver described two headlamps, both giving an approximately parallel beam. The first consisted of a conical reflector, but with a section of a sphere constituting the apex. Light from the source and the spherical reflector was projected by a condenser lens. Light from the source was also collected by a ring lens and projected in a parallel beam on to the conical reflector. Thence it was reflected parallel to that projected by the condenser. In the second lamp, the toric ring and conical reflector were replaced by a paraboloidal reflector, giving the same result.

J. I. Hall described a lens to be used with any standard headlight. The optical axis of the lens was on the periphery and when parallel light was incident on it all the light was projected below this axis.

C. G. Smith's device for preventing dazzle consisted of a glass plate on which was mounted a large number of small specially shaped lenses.

A. Whitehead described a lamp in which the reflector was a deformed paraboloid. The electric lamp had a very compact filament. The deformation of the paraboloid resulted in a primary beam for distant projection and a wide-spreading illumination a few feet ahead of the car.

H. C. Gibson described a device to give the same result. The primary beam was obtained by a Mangin mirror and cylindrical lenses. A conical reflector provided the foreground illumination.

Other lamps were described by A. A. Sandbrook, W. F. Hoare Ward, F. R. Blackmore, and H. J. Simpson.

A long discussion was appended to the collection of papers.

J. R. C.

VII.—Fuels, Refractories, and Furnaces.

371. The Spontaneous Ignition of Coal. Binder (*Chem. Zeitung*, 1922, **47**, 697).—The author concludes that the reason for the spontaneous ignition of coal has not yet been established, and discountenanced the idea that it was due to its pulverised state.

W. S.

372. The Spontaneous Ignition of Coal. Th. Drescher (*Chem. Zeitung*, 1922, **47**, 802).—The author attributed the spontaneous ignition of coal to the pyrites content. W. S.

373. The H. P. Wood Refuse Gas Producer. (*Engineer*, 1921, **132**, 547).—Designed for a suction-gas plant, the gas generator was built of thick steel plates, firebrick lined, with loose fire-bars. The fuel chamber was made large so as to obviate the necessity for frequent charging. Fuel was fed direct into the top of the fuel chamber, but there was no hopper, valve, or slide. Instead of the gas leaving the generator by a single outlet, it was drawn off at four points at the top by vertical pipes which led in pairs to the gas main, sloping down towards the dust collectors. The reason for the multiple outlets was that there might be a uniform draught through the fuel bed at all points and for all loads. From the dust collectors the gas passed to a two-stage, rotary tar-extractor and thence through a sawdust scrubber.

At Messrs. S. J. Moreland's match factory in Gloucester the consumption of fuel originally was 80 tons of best steam coal per week, together with all their wood refuse (waste matches, boxes, chippings, etc.)—approximately 30 to 40 tons per week. The whole of the power required for the factory was, after the installation of the above-described plant, derived entirely from their wood-refuse, giving, apart from other considerations, a direct saving of 80 tons of steam coal per week. F. W. H.

374. The Mechanism of Plasticity from the Colloid Point of View. G. A. Bole (*J. Amer. Cer. Soc.*, 1922, 5, 469).—A brief statement was given of the present conceptions of the colloid chemists. Plasticity, according to the author, was caused by the enveloping film of colloidal material which surrounded the clay grains, this film being of opposite polarity to the grain proper. The addition of an electrolyte, acting as a deflocculant, caused the outer layer of the film to be attracted to an ion of the same polarity as the clay particle, thus reducing the effective diameter and increasing the polarity of the plasticity-inducing particles. For example, if sodium hydroxide were added, the negatively charged OH- ions would attract the outer layers of the film material with greater force than the less negative clay particles, forming a colloidal hydroxide complex which could be assumed to be either a chemical entity or a colloid with an OH-nucleus. The original adsorption equilibrium was upset, but equilibrium was subsequently restored again.

The reduction of the effective diameters of the particles reduced friction, whilst the displacement of practically electrically neutral bodies by bodies with like charges (negative) introduced repulsive forces which permitted mobility. The result was a fall in viscosity. A flocculating ion caused an opposite action, increased the depth of the colloid film, thereby increasing the area of surface in actual contact, but decreased the repulsive force.

The flocculating or deflocculating effect of the ions of an electrolyte depended, not only on their polarity and concentration, but also on their transport numbers, the more rapidly moving H- and OH- ions having the greater effect.

The method of measuring plasticity by "touch" was proved by experiment to be untrustworthy, and a plea was made for a unit and standard method of measurement. F. W. H.

375. Asbestos in 1920. E. Sampson (Washington: United States Geological Survey. 1922. 14 pp.). F. W. H.

376. Refractory Compositions. E. C. R. Marks, London, and Buffalo Refractory Corporation, Buffalo, New York, U.S.A. (Brit. Pat., No. **176436**, November 2nd, 1920).—The patent refers to a refractory composition comprised of silicon carbide, flake or crystalline graphite, a flux, and a carbonising binder, such as tar or molasses. As fluxes, clay, salts, such as borax, metallic or non-metallic oxides or sulphides may be used. The mixture is moulded in the usual manner and baked at about 1000°. Suitable proportions of the ingredients are 68 parts of silicon carbide, 25 parts of graphite, and 7 parts of flux, or of flux and binder. The composition is suitable for making heat-resisting articles such as crucibles, fire-bricks, retorts, muffles, furnace cores, tubes, combustion boats, pyrometer tubes, furnace linings, and heat-resisting cements.

See also specification: Brit. Pat., No. **176437**, November 2nd, 1920. H. G. C.

377. Discussion on "A Small Glass Tank" (*J. Amer. Cer. Soc. Bull.*, 1922, **1**, 250).—H. T. Bellamy, replying to questions, asked concerning his small tank (this Journal, Abs., 1922, **6**, 136) stated that zirkite brick was used principally to withstand the severe action on the arch of the flames playing directly on it. This day-tank was operated for more than twelve months at a temperature of about 1315° melting a high lead glass. The arch, on which the flames impinged, was the hottest part of the furnace, yet no spalling whatever had occurred. The insulation of the crown was such that it resulted in a temperature not exceeding 100° on the top. Since the zirconium silicate brick did not harden, the arch had been taken apart brick by brick and set up again, a great consideration when using expensive bricks.

He also stated that he had used blue water gas for four or five years in melting small quantities of glass and had never noticed any serious defects in the product. However, where large quantities might be used passing through mains where the gas might come into contact with iron, iron carbonyl was formed. The decomposition of this unstable gas in the furnace forming carbon monoxide and iron oxide would result in the glass being discoloured.

F. W. H.

378. Reheating Glass Electrically. E. F. Collins (*Glass Industry*, 1922, **3**, 223).—The temperature of the electric metallic resister furnace was so easily controlled that any temperature combination for the drawing or rolling of glass was possible. Common glass was transparent to light and heat beyond the violet rays of the solar spectrum, but very athermous to the longer heat rays; for example, at 100°, 2·6 mm. intercepted all heat radiations, at 390°, only 6 per cent. In the metallic resister furnace, the ratio convected heat/radiated heat was 20/100 at 260° and 3/100 at 871°, so that at moulding temperatures the reheating was almost entirely due to radiant heat. W. S.

379. Temperatures in Glass Melting Furnaces. Loesser (*Ker. Rundschau*, 1922, **5**, 48).—The author considered a recuperative tank furnace of the Nehse-Dralle type, having a double horseshoe flame, and used for melting sheet glass, data for which were given in Dralle's *Die Glasfabrikation*, Vol. I, p. 563. The measured temperatures were: Flame temperature in melting zone, 1600—1650°; at the surface of the glass, 1497—1526°; in both ports, 1320—1385°. The tank was 6 m. wide and 8·5 m. maximum length. The ports were all in the end of the furnace, the inlet ports being in the middle and an outlet port at each side of the end wall. The measurements were probably made in the convenient cross-section between the two filling-on holes and therefore about 2 m. from the ports. The author pointed out that the flame temperature would vary on account of the variation in the quantity and quality of the gas, alteration of the slack damper position and difficulty of measurement owing to the returning gas stream having undergone a temperature fall. He asserted that 1600—1650°

was probably not the hottest temperature attained, as the point of measurement was too near the inlet ports and referred to measurements made by Mayer.* The latter measured a temperature of 1750° in the middle of a regenerative pot furnace, that is, at a distance 5 m. from the ports. The temperature was still well above 1500°, and was assumed to be the necessary temperature for successful melting. The distinctly lower temperature in the recuperative furnace was not due to poor quality coal. The gas entered the furnace at 600°. The air entered at 830—890°. The author concluded that although a higher flame temperature than 1600—1650° was reached, it would not reach 1750° like the regenerative furnace. Regarding the temperature fall of the flames, he contrasted the data for the pot furnace which gave the temperature in the two ports as 1320—1380 with that of the regenerative furnace referred to above. In the latter case, the length of the path of the gases in the furnace was 10·3 m. and temperatures were 1640° at the inlet port, 1750° in the middle, and 1290° at the exit port. He thought the recuperative furnace was inefficient because the maximum flame temperature could only be attained in an unfavourable place (near the refining zone) and in an insufficient portion of the tank. In actual practice, the average monthly production of glass from three of these tanks was 4746 kg. per square metre of melting area, contrasted with about 7000 kg. per square metre for a large number of regenerative tank furnaces. The coal consumption, including that of the lehrs, was 1·5 kg. of coal per kg. of glass. With this design of furnace, the batch had to be thrown as far as possible into the middle of the furnace; this was due to the fact that the returning flames which had suffered a temperature fall were led along the relatively "cold" sides of the furnace. The author suggested that the positions of the inlet and exit ports should be reversed and that perhaps a common exit port should be used. He claimed that this would give a larger effective melting area and so increase the productive capacity of the tank.

The author deplored the lack of data, and the small degree of accuracy of the data available, for scientific furnace design. He appealed for systematic collection of such data, in spite of difficulties and expense. H. W. H.

380. An Improved Lehr for Annealing Plate Glass. E. E. Milner, W. J. Lytle, and H. L. Dixon Co. (U.S.A. Pat., No. **1426310**, August 15th, 1922. Filed August 16th, 1921, No. 492660).—The specification describes and illustrates a muffle lehr for annealing plate glass in which heating is effected by radiation from combustion chambers or flues which form the roof and one wall of the lehr. The plates are moved through a number of chambers into which the lehr is divided and the chambers are arranged zigzag with respect to one another. G. D.

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* Dralle, Vol. I, pp. 430 and 431, and *Ker. Rundschau*, 1922, **30**, 329.

381. Furnaces. Wellman Smith Owen Engineering Corporation, Ltd., and A. V. Kemp, London (Brit. Pat., No. **181863**, April 1st, 1921).—In a furnace for heating metals, melting glass-making materials, etc., in which two passages, *A*, *B*, are formed on the crown, the lower for heating the air for combustion and the upper for the escape of the waste gases, baffles are formed by bricks, b^3, extending from the arches into the passages. As shown, in each transverse row, every fourth brick is longer than the remainder, and in adjacent rows the projecting bricks are out of line.

H. G. C.

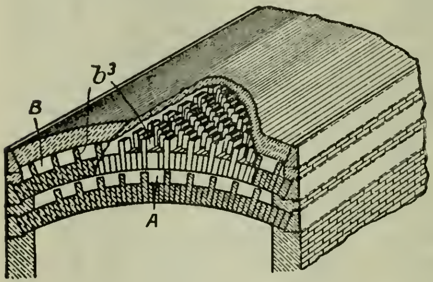

Fig. 192.

382. Improvements in Pot Furnaces. M. W. Travers, London (Brit. Pat., No. **177085**, May 3rd, 1921).—In a gas-fired furnace for heating melting-pots for glass, gas from the producers, *C*, is supplied with secondary air under pressure from inlets, *J*, to effect its combustion as it rises through the eye, *B*, into the furnace. The air is supplied by a blower, *G*, connected by the main, *H*, and pipes, *I*, to the air-inlets, *J*.

H. G. C.

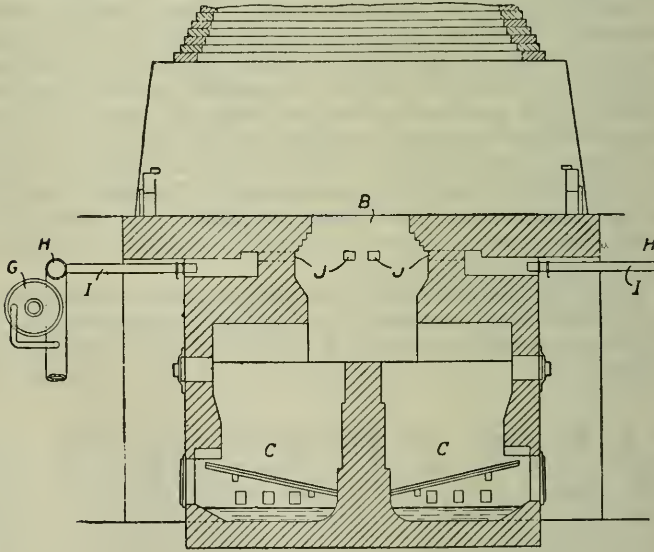

Fig. 193.

383. Glass Annealing Furnaces. Soc. des Verriers de Folembray, Folembray, Aisne, France (Brit. Pat., No. **182109**, June 16th, 1922. Convention date, June 22nd, 1921. Not yet accepted).—A gas-fired glass-annealing "tunnel or arch" is heated by two sets of burners one set in the roof being of usual arrangement while the others, 2, beneath the sole or in other suitable position, deliver into a combustion chamber, 3, separated from the annealing-chamber by heat absorbing chequer brickwork, 4. Air is supplied at 1, preheated in a recuperator arranged adjacent to the glass furnace recuperator. Gas is supplied by a separate producer or from the main producer, battery. H. G. C.

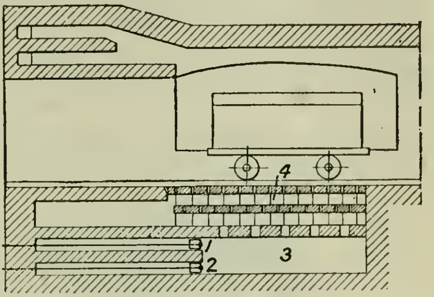

Fig. 194.

384. A Recuperative Tank Furnace. W. McLaughlin and C. C. Norton (U.S.A. Pat., **1432706**, October 17th, 1922. Filed April 20th, 1920, No. 375334).—The invention consists of a recuperative tank furnace, shown in plan, partly in section, in Fig. 195.

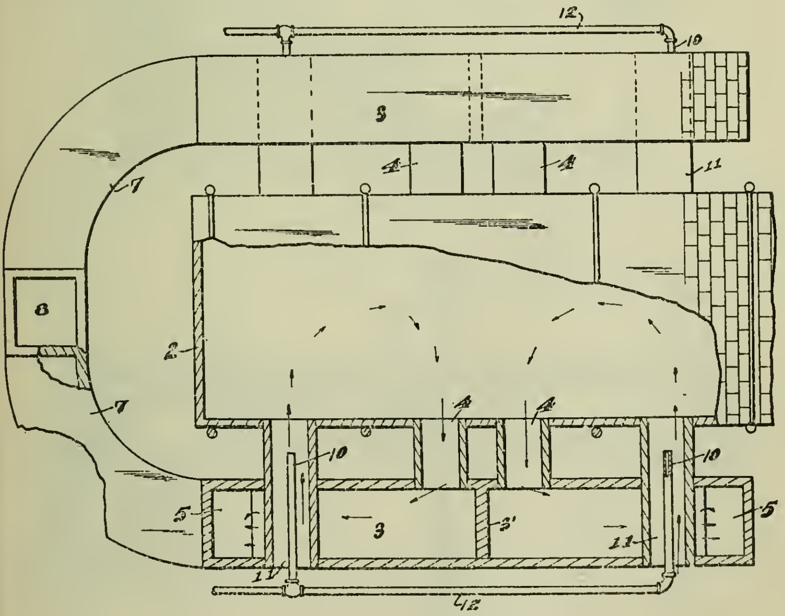

Fig. 195.

The fuel is supplied by burners, 10, arranged in tubes or flues, 11, which project from the side of the tank, 2, and serve for the admission of the air supply. The hot gases leave the tank by flues, 4, which lead into flues, 3, connected with the stack, 8, by way of lower flues, 7. The flues, 3, surround the air flues, 11, so that the heat of the burnt gases is used to heat the flues, 3, and, therefore, the supply of air for the burners. G. D.

385. An Improved Flattening Oven. E. E. Milner, W. L. Lytle, and H. L. Dixon Co. (U.S.A. Pat., No. **1426309**, August

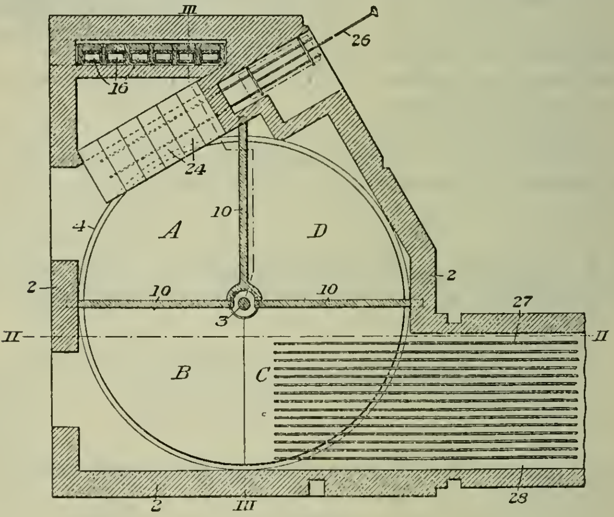

Fig. 196.

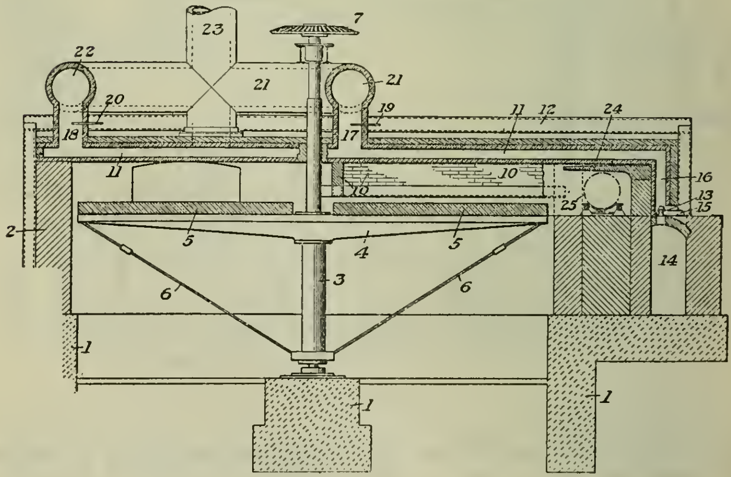

Fig. 197.

15th, 1922. Filed August 12th, 1921, No. 491701).—The invention consists of a muffle flattening oven which is fitted with means to enable the temperature of its different parts to be regulated to secure the desired heat distribution. The flattening stones, 5, are carried by a table, 4, Figs. 196 and 197, which is supported and rotated by a shaft, 3, in a chamber formed by walls, 2, and built on the end of the lehr, 28. The chamber is divided by overhanging partitions, 10, into four compartments, *A*, *B*, *C*, *D*, of which *A* is the flattening oven, *B* is the piling station, *C* is the station where the sheets are transferred to the lehr rods, and *D* is a "dummy" oven. Heating is effected by flues, 11, Fig. 197, which are formed across the roof of the chamber. Each flue is supplied with a burner, 13, and an air inlet, 15, and communicates with the stack by way of offtakes, 17, 18, and flues, 21, 22. The combustion of the gas in the flues heats the oven by radiation, and dampers, 19, 20, enable the temperature of the oven and the distribution of the heat to be regulated. The cylinders, 25, are introduced into the oven by a tool, 26, and a shadow wall, 24, protects them from being too highly heated immediately they are placed in the door. After flattening, the movement of the table transfers the sheet from station *A* to station *B*, where it is lifted off the stone and placed on the rods of the lehr. G. D.

VIII. Chemical Analysis.

386. The Estimation of Arsenic Acid. L. ROSENTHAL (*Zeitsch. analyt. Chem.*, 1922, **61**, 222).—In the estimation of arsenic by titration with a solution of iodine the author recommended the addition of 5 gm. of sodium bicarbonate before adding potassium iodide to the arsenic salution. This prevented the reaction of atmospheric oxygen with the hydriodic acid formed during titration to produce free iodine.

The solution for titration should contain at least 16 per cent. of hydrochloric acid or 33·3 per cent. of sulphuric acid. Using the latter acid, the arsenate solution was treated with concentrated sulphuric acid to bring the concentration to 33·3 per cent. After cooling, the sodium bicarbonate was added in small quantities at a time, concentrated potassium iodide solution added, and the liberated iodine titrated against decinormal thiosulphate solution. A precipitate might be formed on addition of the potassium iodide. This consisted chiefly of arsenic tri-iodide and should be dissolved, before titration, by the addition of a small quantity of water.

Diffused light did not interfere with the estimation. F. W. H.

387. The Microchemical Investigation of Arsenic. A. PIUTTI and E. BOGGIO-LERA (*Mem. Accad. Lincei*, 1922, [v], **13**, 475; from *J. Chem. Soc.*, 1922, **122**, ii, 584).—The reagent used was composed of 1 c.c. of 3 per cent. ammonium molybdate solution, 10 c.c. of 3·4 per cent. ammonium nitrate solution and 39 c.c. of 40 per cent. nitric acid solution. With liquids containing 0·02 to 0·004 mg. of arsenic per c.c., this reagent was used directly, but for lower concentrations of arsenic the reagent was diluted five times with 40 per cent. nitric acid. A drop of the arsenic solution yielded characteristic microscopic crystals when evaporated with a drop of the reagent. As little as 0·00005 mg. of arsenic could, according to the authors, be detected by this method.

F. W. H.

388. The Iodometric Estimation of Arsenic and Antimony Sulphides. F. Nikolai (*Zeitsch. analyt. Chem.*, 1922, **61**, 257).—The trisulphide of arsenic, or antimony, was dissolved in sodium hydroxide solution and added to a solution of iodine containing acetic acid and sodium acetate. The excess of iodine was then titrated with thiosulphate solution. The alkaline solution of the sulphide was readily oxidised in the atmosphere, but this might be prevented, or at least retarded, by the addition of a little gelatine.

Arsenites and the corresponding antimony salts could be similarly estimated, omitting the solution in sodium hydroxide.

F. W. H.

389. The Rapid Estimation of Sulphur. L. Losana (*Giorn. Chim. Ind. Appl.*, 1922, **4**, 204; from *J. Chem. Soc.*, 1922, **122**, ii, 582).—If the compound containing sulphur were heated with powdered iron out of air, the sulphur in the residual mass was liberated completely as hydrogen sulphide on subsequent treatment with hydrochloric acid. The gas was absorbed by zinc acetate solution and the sulphide thus formed estimated by titration with iodine solution. Tests made on flowers of sulphur and on copper, lead, barium, and cobalt sulphates gave excellent results.

F. W. H.

390. The Oxygen-absorption and Concentration of Pyrogallol Solutions used in Gas Analysis. F. Hoffmann (*Zeitsch. angew. Chem.*, 1922, **35**, 325).—The author gave a triangular diagram showing the absorptive powers for oxygen of mixtures of pyrogallol, potassium hydroxide, and water. The best proportions for use were given as pyrogallol 20 parts, potassium hydroxide 20 parts, and water 60 parts by weight. F. W. H.

391. Atkinson's Process for the Estimation of Potassium in the Presence of Sodium, Magnesium, Sulphates, and Phosphates. S. J. Watson (*Analyst*, 1922, **47**, 285).—The process was considered both unsatisfactory, owing to the loss of potassium chlorate, and uneconomical, since large quantities of methyl alcohol and perchloric acid were used. F. W. H.

392. The Volumetric Estimation of Titanium Dioxide in Bauxite. H. J. Winch and V. L. Chandratreya (*Chem. News*, 1922, **124**, 231).—About 0·3 gm. of bauxite was intimately mixed with 3 gm. of potassium persulphate, fused and extracted with hydrochloric acid. The solution was then boiled with 0·15 gm. of powdered tin and 5 gm. of ammonium chloride until all the tin had dissolved. After the addition of cold water to the solution, 50 c.c. of a 4 per cent. solution of mercuric chloride were added to remove any excess of stannous chloride. So long as the solution was kept cold the mercuric chloride would not oxidise the titanous chloride. To the cold solution was added 5 c.c. of ferric chloride solution (1 c.c. = 0·01 gm. of iron) and the liquid titrated with potassium dichromate solution.

A blank estimation of the iron was carried out on a separate sample, using stannous chloride for reduction and the same potassium dichromate solution for titration. The difference between the two titration readings corresponded with the amount of titanium present. F. W. H.

393. A Rapid Method of Analysis for Dolomite and Magnesian Limestone. S. D. Averitt (*J. Ind. Eng. Chem.*, 1922, **14**, 1139).—Half a gram of finely ground limestone was decomposed in a wide-mouthed 150 c.c. flask, with 25 c.c. *N*/2-HCl. Hot water was added to maintain the volume, and to wash down the flask. After cooling, the excess of acid was titrated with *N*/4-NaOH, using methyl-orange as indicator. The volume of NaOH used was read, then 10 c.c. of a 10 per cent. solution of NH_4Cl and two drops of NH_4OH were added. The solution was heated gently to flocculate the ammonia precipitate. This precipitate and the insoluble residue were filtered on a dried and tared filter, washed well with hot water, dried at 100—105° and weighed. To this weight (B) of ammonia precipitate and insoluble, a small correction (M) varying from 0·02 to 0·05 per cent. for pure specimens, or up to 0·20 per cent. for others containing considerable amounts of insoluble, had to be added. A clayey insoluble contained more moisture than a sandy one, and from the nature of the insoluble the moisture correction was judged.

From the NaOH titration value, the calcium carbonate equivalent (A) of the sample was calculated. The weight (B) of ammonia precipitate and insoluble had been determined, and the moisture (M) was assumed, and from these values the magnesium carbonate content was calculated as follows :

The factor (a) for converting CO_2 into $CaCO_3 = 2·274$ and the converting factor (b) for CO_2 into $MgCO_3 = 1·916$. When X and Y represent the quantities of CO_2 in a sample combined as $CaCO_3$ and $MgCO_3$, respectively, then

$$aX + bY = 100 - (B + M) \quad . \; . \; . \; . \; . \; . \; . \quad (1)$$

Also,

$$A = aX + aY \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

hence,

$$bY = \left[\frac{A - \{100 - (B + M)\}}{a - b}\right]b \quad . \; . \; . \; . \; . \quad (3)$$

But

$$\frac{b}{a - b} = \frac{1·916}{0·358} = 5·35.$$

Therefore, bY, the $MgCO_3$ content of the sample, is given by

$$bY = 5{\cdot}35[A - \{100 - (B + M)\}] \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Again,

$$100 - (B + M) = CaCO_3 + MgCO_3 \quad . \quad . \quad . \quad . \quad . \quad (5)$$

in percentage compositions.

Using equations 4 and 5, after having determined B and A experimentally, and assumed M, the calcium carbonate and magnesium carbonate contents of a sample could be calculated.

This method was compared with the differential method, the $CaCO_3$ of which was actually determined, on more than 50 samples of magnesian limestone containing from 3·2 to 42·8 per cent. $MgCO_3$, and of varying degrees of impurity. The method was found as accurate as the differential method; the greatest difference in values of $MgCO_3$ per cent. was 0·5. V. D.

394. The Determination of Aluminium as Phosphate. G. E. F. Lundell and H. B. Knowles (*J. Ind. Eng. Chem.*, 1922, **14**, 1136).—Tests were carried out to determine the trustworthiness of the quantitative determination of aluminium as phosphate, both in acid and in alkaline solutions. The results showed that the method did not, in general, yield accurate values. When only very small quantities (1 to 5 mg.) of aluminium were present, the results were acceptable, but when larger amounts were involved the method was far from trustworthy. High values resulted when more than 5 mg. of aluminium were precipitated by the ordinary procedure. Use of a weak acid wash or immoderate washing gave low values, as was also the case when only a slight excess of the precipitating agent was used, and when the precipitation was performed in alkaline solution.

When precipitated in like manner, iron behaved like aluminium; titanium invariably gave low results. V. D.

395. Volumetric Estimation of Aluminium.—E. J. Kraus (*Chem. Zeitung*, 1921, **46**, 1173).—The principle adopted was similar to that used in the estimation of Cl in water by means of $AgNO_3$ and $KCrO_4$ solutions.

$$1.\ Al_2(SO_4)_3 + 2Na_2HPO_4 \rightleftharpoons 2AlPO_4 + 2Na_2SO_4 + H_2SO_4.$$

$$2.\ 2Na_2HPO_4 + 3AgNO_3 \rightleftharpoons \underset{\substack{\downarrow \\ \text{(yellow)}}}{Ag_3PO_4} + 3NaNO_3 + NaH_2PO_4.$$

For this method it was possible to use the precipitate obtained with ammonia from aluminium and iron containing solutions, the separation of the metals being effected by boiling with a solution of caustic soda or caustic potash, which retained the aluminium in solution:

$$Al(OH)_3 + NaOH \rightleftharpoons AlO{\cdot}ONa + 2H_2O.$$

This filtrate was first acidified with dilute sulphuric acid, and the hydrated alumina reprecipitated by ammonia in a porcelain dish and dissolved again in dilute sulphuric acid in order to obtain the aluminium sulphate free from deleterious matter.

$$2Al(OH)_3 \leftarrow \boxed{\cancel{Al(OH)_3}} + 3H_2SO_4 \rightleftharpoons Al_2SO_4 + 6H_2O.$$

This solution was brought to boiling point, and Na_2HPO_4 run in from a burette, whilst $AgNO_3$ was used as indicator (at boiling point, because the yellow colour of the Ag_3PO_4 varied with temperature) giving the yellow coloration when excess Na_2HPO_4 was present.

It was claimed that the method was particularly good for small quantities of Al, for example, in natural waters, substances with low aluminium content, or very dilute aluminium solutions. W. S.

396. Gravimetric Estimation of Nickel as Nickel Dioxide. W. VAUBEL (*Chem. Zeitung*, 1922, **47**, 978).—The author had obtained satisfactory results by the method outlined below, but care must be taken that it was the dioxide which was formed.

The hydroxide precipitated by NaOH was washed, dried, and heated, the precipitate being thoroughly freed from traces of alkali on the filter. It was then dried again, the filter ignited with the precipitate, and the residue dissolved in nitric acid in a crucible, the excess of nitric acid being evaporated off on a thick asbestos plate. The crucible was then ignited with its contents for half an hour in an air oven at 280—330°. The black residue was nickel dioxide. W. S.

IX.—Machinery for the Working of Glass.

397. Method of Forming Pressed Glass Articles. E. A. HAILWOOD, Churwell, near Leeds (Brit. Pat., No. **181434**, March 5th, 1921).—A device for pressing articles from glass comprises a mould, a cup for measuring the quantity of glass to be pressed, and a device for giving the article an auxiliary or secondary squeeze after it has been formed in the mould by the plunger of the press. In the construction shown in Fig. 198, a measuring-cup, *C*, having a removable base, C^1, is mounted above the mould. The cup, *C*, is of such dimensions, or is provided with indicating-marks, C^2, that the correct quantity of glass to form the article can be gauged. After filling, the base, C^1, can be drawn away to allow the glass to fall into the mould. The plunger, *P*, moves down through the cup to press the glass, and the plunger is provided with a sleeve, P^1, which, either by itself or by acting on a flange, P^x, in the

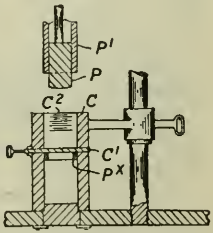

FIG. 198.

mould, brings an additional pressure on the article after formation to size it and to squeeze out bubbles. In a modification, instead of having a removable bottom, the cup may be supported on trunnions and tilted to pour its contents into the mould. In other modifications, one cup may serve several moulds, or there may be a series of cups mounted on a wheel to empty their contents into moulds as they are brought into the desired position.

H. G. C.

398. Hand-operated Bottle Machine with Suction Gathering. J. Wolf, Cologne, Germany (Brit. Pat., No. **179422**, April 27th, 1921).—Relates to a pneumatically operated hand-controlled bottle-blowing machine of the suction gathering type. According to the invention, the parison mould, 21, is lifted, after gathering, by a cylinder, 10, the port, 24, moves out of register with the vacuum pipes, 23, 23*a*, 23*b*, 23*c*, and the cut-off knife, 52, is pushed forward by the cylinder, 46. The parison mould, 21, is opened by a cylinder, 42, and the structure carrying the neck mould, 20, is drawn back by a cylinder, 26, so as to bring the parison, which is supported on the knife, 52, into the blowing mould, 28. The compressed air for all operations is controlled by a single multiple-port hand-operated valve. The movement of the parison being lateral, there is less tendency to elongation than when the movement is upwards from parison to blowing mould.

H. G. C.

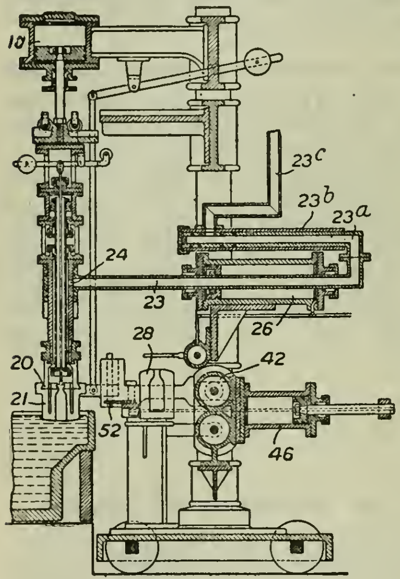

Fig. 199.

399. Glass-forming Moulds. C. R. Lott, Washington, Columbia, Assignor to the Guardian Trust and Savings Bank, Toledo, Ohio, U.S.A. (U.S.A. Pat., No. **1369679**, February 22nd, 1921. Filed September 27th, 1909, No. 519678. Divided and filed March 15th, 1920, No. 365783).—According to this invention, a parison mould consists of three portions, namely, a body portion, a movable bottom, and an upper portion which includes the neck ring and the shoulders of the mould in one piece.

With the bottom plug in its lowest position, and the top portion removed, a charge of glass is fed into the body portion of the mould. The upper portion is replaced and held tightly in position by springs while the bottom plug is forced upwards, thus pressing the glass into the neck ring and forming the neck of the bottle. It is claimed that this method of building up a mould is very suitable for long-necked ware, as the positive driving of the glass ensures the complete filling of the neck ring. S. E.

400. Apparatus for Conveying Molten Glass. J. B. GRAHAM, Evansville, Indiana, U.S.A., and R. LA FRANCE, Toledo, Ohio, U.S.A., Assignors to the OWENS BOTTLE MACHINE Co. (U.S.A. Pat., No. **1350448**, August 24th, 1920. Filed April 17th, 1918, No. 229010).—This apparatus is designed to supply a plurality of forming machines from a single gob-forming device, the successive charges being directed alternately to the moulds of the two machines. In its preferred form a pair of curved troughs or chutes are connected together and mounted to oscillate about a vertical axis, thus bringing the chutes alternately into position to receive a charge from the feeding device. Each trough delivers its charge to one or other of two stationary troughs which convey the gob of glass to the forming moulds of the machine. The shaft which oscillates the two distributing chutes is geared so as to be operated in timed relation to the gob-forming apparatus and also to the rotary movements of the mould table. S. E.

401. Method of Delivering Charges of Glass. H. BLANC, Paris (Brit. Pat., No. **182011**, July 27th, 1921).—A method of gathering molten glass for delivery to forming-machines consists in cooling part of the metal in a tank, withdrawing part of the cooled metal, and then reheating the metal so withdrawn to restore its fluidity so that it flows into a ladle or other delivery device. The apparatus comprises a helical coil of tubing, 4, which is immersed in the metal in a tank, 1, and through which water can be circulated to chill the metal adjacent to the coil to form a well or gathering-space. The gatherer consists of a similar coil of tubing, 12, but of smaller diameter, which is suspended from a block, 15, having a pivot journalled in a slot, 18, in a disc, 8. The disc is supported above the crown of the tank and oscillates about a shaft, 9. A pot, 19, is supported above the surface of the metal by a wall, 2, built up from the floor of the tank. In operation, the gatherer, 12, dips into the metal, as shown, and the metal is chilled about the tubes and forms a crust which encloses more fluid metal. The movement of the disc lifts the gatherer over the pot, and the block, 15, moves in the slot, 18, thus giving the gatherer a jerk which detaches the metal and drops it into the pot, 19. Further, the hot gases in the tank melt off any metal

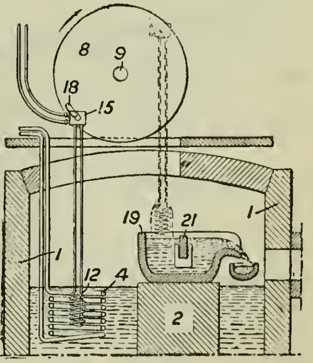

FIG. 200.

adhering to the gatherer. After falling into the pot, the metal eventually flows under a bridge, 21, and over a spout into a ladle or other delivery device. Instead of using the disc, 8, the gatherer may be reciprocated vertically and also rotated about a vertical axis. The coil, 4, for forming the gathering-space may be replaced by two flat coils of tubing and two plain partitions placed at right-angles to one another. H. G. C.

402. Glass Delivery Apparatus. R. T. McGee, Wheeling, West Virginia (U.S.A. Pat., No. **1394920**, October 25th, 1921. Filed May 22nd, 1919, No. 298903).—Glass is allowed to flow from a melting tank through a conduit, 3 (Fig. 201), into a valve chamber, 5, and thence onward into a reservoir, 9, and a well, 7. The upper ends of the well and reservoir are open and are above the normal working level of the tank. The conduits and well, and the lower portion of the reservoir, are constructed of refractory material and are heated by burners, 14. The upper part of the reservoir, 15, is water cooled, so that the surface layer of glass may be cooled until semi-solid, and thus forms an elastic diaphragm. Disposed above this diaphragm is a plunger, 16, which may be depressed, displacing the glass in the reservoir, and causing it to rise in the well, 7, thus filling the mould stationed over the mouth of this well. The check valve, 19, prevents the flowing back of glass into the tank during this operation. S. E.

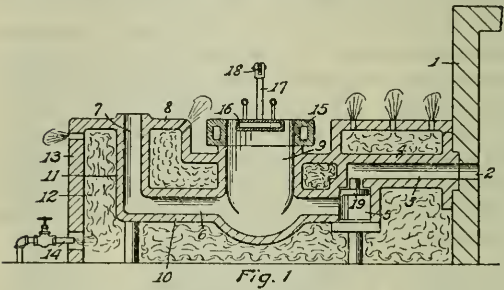

Fig. 201.

403. Apparatus for Feeding Molten Glass. K. E. Peiler, West Hartford, Connecticut, U.S.A., Assignor to Hartford-Fairmont Co., Canajoharie, New York, U.S.A. (U.S.A. Pat., No. **1405936**, February 7th, 1922. Filed July 17th, 1920, No. 396935).—In this feeding device, glass is allowed to flow through an orifice in the bottom of a forehearth forming an extension from the usual melting tank. Over the outflow orifice is suspended a bell of refractory material which may be raised or lowered so as to control the rate of outflow. The flowing stream of glass is segregated into gobs by means of the air in the bell being subjected alternately to reduced and increased pressures. During the period when the air in the bell is subjected to reduced pressure, the glass flowing under the edge of the bell is sucked up into it, while during the period when the compressed air is acting, the glass from the bell is forced out through the orifice in the form of a mould charge. Shears are provided and timed to cut off the charge just below the outlet at or about the moment when the reduced pressure of air is beginning to act. The means for providing the variation of air pressure in the bell is a pump, comprising a cylinder, reciprocating piston and co-operating valves. Movement is imparted to the piston by means of a lever, one end of which carries a roll which co-operates with a cam on the main shaft. The path of this cam is of such a shape as to produce full movement of the piston, preferably with a dwell at each end of the stroke. The shape of the charge formed below the outlet may be controlled within certain limits by the variation of the air pressure in the bell, which produces a corresponding variation in the rate of extrusion, and thereby varies the diameter of the charge being delivered. In order to allow the air pressure in the bell to return quickly to the normal, two adjustable and mechanically operated valves are provided, one to relieve the vacuum and the other to relieve the compression. Thus, the duration of the vacuum and compression may be varied. S. E.

404. Glass Distributing Device. A. R. HUNTER, Hartford, Connecticut, U.S.A., Assignor to HARTFORD-FAIRMONT CO., Canajoharie, New York, U.S.A. (U.S.A. Pat., No. **1353115**, September 14th, 1920. Filed November 12th, 1917, No. 201469).—In plants which have one gob-forming device feeding two or three forming machines, it is sometimes necessary to stop one machine for a short space of time, but it is advisable to keep the others running and to keep the feeding device working at its normal rate. In such cases, the charges of glass must be deflected from the machine which is temporarily out of action.

The charges of molten glass are normally delivered to the working machine by means of a series of troughs, mounted on the framework, 1, Fig. 202, the lower end of which is carried on an oscillating bracket, 8, attached to the shaft, 9, which is driven by any suitable means. On a bedplate, 21, is mounted a standard, 20, carrying a deflector chute, 17, which is capable of rotation about the standard so as to allow its upper end to lie in the path of the gob in between the end of the delivery chute and the mould. The lower end extends over a cullet pit or receptacle. When the machines are working normally

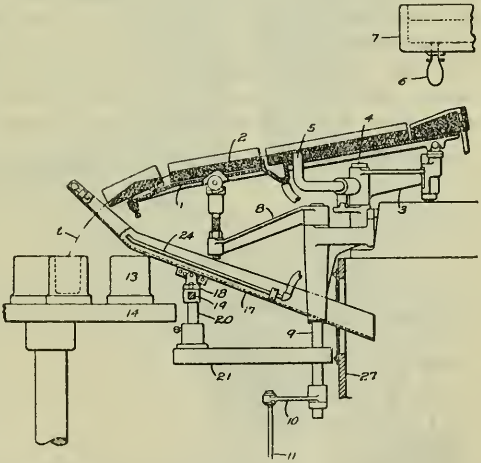

FIG. 202.

the deflector chute lies idly between the tables of the machines, but when it is desired to stop one machine the upper end of the deflector is rotated until it stands over the mould in the charging position, thus intercepting and diverting the charges to the cullet pit. S. E.

405. A Feeder for Molten Glass. K. E. Peiler, Hartford, Connecticut, U.S.A., Assignor to Hartford-Fairmont Co., Canajoharie, New York, U.S.A. (U.S.A. Pat., No. **1277255**, August 27th, 1918. Filed August 7th, 1912, No. 713738).—A forehearth extending from a melting tank is provided at its front end with a lip which is rather lower than the sides of the extension and slightly above the normal level of the glass in the tank. Mounted above this extension is a series of displacing members or plungers which are capable of being raised and lowered by a series of cams. The gate displacer, 13 (Fig. 203), is nearly as wide as the interior of the extension, so that when lowered into the position shown, it fairly effectively prevents any flow of glass to or from the tank, and at the same time causes a rise in the level of the glass between it and the spout. The other displacer, 12, is then depressed into the glass, thus causing a further rise in its level and causing it to flow over the spot in the form of a pear-shaped gob, 10, the neck of which is severed by shears, 44 and 45. By slightly raising the plunger, 12, the shearing is made easier, and the depending stub of glass to be drawn back into the extension, where it is reincorporated with the hot metal. S. E.

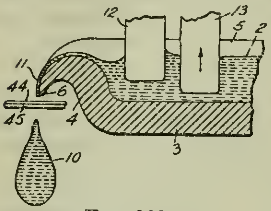

Fig. 203.

406. Mechanism for Flow Feeding Device. T. Stenhouse, Washington, Pa., U.S.A., Assignor to Hagel-Atlas Glass Co., Wheeling, W. Va., U.S.A. (U.S.A. Pat., No. **1265827**, May 14th, 1918. Filed October 23rd, 1914, No. 868169. Renewed September 23rd, 1916, No. 121907).—Glass flows from an orifice, 2 (Fig. 204), through an elongated orifice, 10, into an auxiliary spout, *B*, whence it flows through a discharge orifice, 11, and the aperture, 12, in the base plate, into a chamber formed by the cut off members, 25. The centre of the discharge orifice, 11, and the cut off

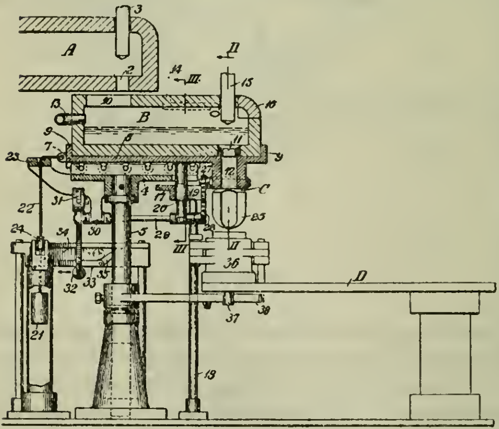

Fig. 204.

mechanism, *C*, are always maintained at the same distance from the centre of the rotating table, and exactly above the centres of the moulds by means of a cam track, 17, against which a roller, 20, is held by the counterweight, 21. The auxiliary spout is normally held in position by the weight, 21, except during the time when it is being carried forward by the stop, 37. As the table rotates, carrying with it the auxiliary spout, the cut off members are opened, thus allowing the stream of glass to flow straight into the continuously rotating mould. The glass continues to flow until the instant the stop, 37, clears the arm, 38, when the cut off mechanism is closed, thus forming a cup for collecting the glass during the return movement of the spout under the action of a counterweight, and until another mould comes into position and the forward movement starts again. S. E.

407. Drop Feeding Device for Glass Machines. A. L. Schram, Hillsboro, Illinois, U.S.A., Assignor to Drey Automatic Glass Machine Co., St. Louis, Missouri, U.S.A. (U.S.A. Pat., No. **1353276**, September 21st, 1920. Filed August 28th, 1915, No. 47719).—Into the base of an extension from a melting furnace is fitted a flow block, 16 (Fig. 205), of refractory material, and secured to the metal framework is a ring, 19, which has a hole of larger diameter than the flow tube. In between these two is a water-cooled metallic ring, 24, the faces of which incline outwards, so as not to retain any glass that may fill the cavity in the case of a stoppage. Mounted below the plate, 19, are two slidable cup elements, 26, which are also water cooled, 29, and serve with the aid of the water-cooled knife, 32, to retain the glass as it flows from the furnace until it is dropped into the forming mould by the withdrawal of the knife and the separation of the two halves of the cup. S. E.

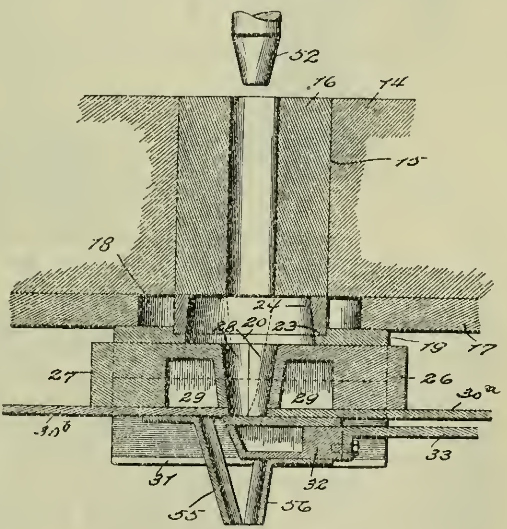

Fig. 205.

408. A Glass-Feeding Device. J. M. Said and The Corning Glass Works (U.S.A. Pat., No. **1424184**, August 1st, 1922. Filed February 9th, 1921, No. 443663).—The specification describes an automatic feeding-device in which a ladle scoops up a charge or gob of glass from a mass of metal, and is then carried outwardly and inverted to cause the gob to fall into a receptacle, such as a mould. It is stated that the device is particularly designed for slow work and intended to deliver the gobs at a speed not exceeding ten a minute. As shown in Figs. 206 and 207, the supply of metal is, 6, contained in a forehearth, 5, which is covered by a hood, 8, that retains the heat from auxiliary burners. The gobs are gathered and delivered by a scoop or ladle, 9, of refractory material, mounted on a hollow water-cooled shaft, 10, that is journalled in a swinging frame, 13. Mechanism is provided to oscillate the frame, 13, and to turn the shaft, 10, at appropriate intervals; means for adjusting the height of the ladle and its movement also being provided.

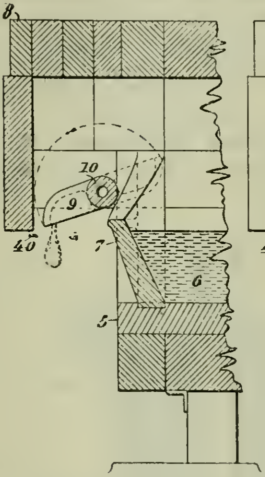

Fig. 206.

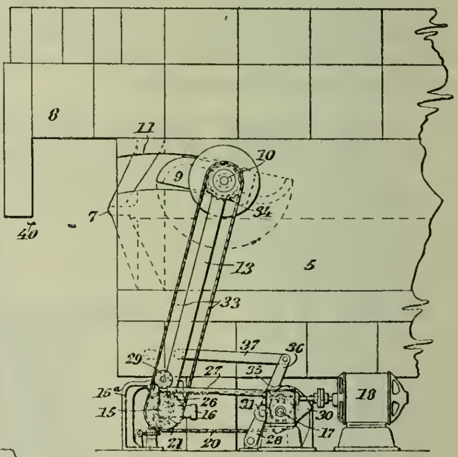

Fig. 207.

At the beginning of a cycle of operations, the ladle is in the position shown in Fig. 207. It is then turned through an angle of about 180° to the position shown in dotted lines, and during this movement, it dips into the metal, 5, and scoops up a gob. The frame now swings forward to bring the ladle beyond the edge of the forehearth. A further rotation of the ladle, to the position shown in Fig. 206, delivers the gob into a mould. Shears, 40, of suitable design can be provided for severing the gob from the glass left on the ladle. G. D.

409. Shears for Glass Feeding Devices. M. White, York, and A. E. Clegg, Leeds (Brit. Pat., No. **181233**, May 28th, 1921).—Relates to shearing-mechanism for use with flow feed delivery apparatus of the type in which the shear-arms, 7, are held back by springs, 9, until, as the mechanism is moved forward along the slide, 5, pins, $7^{\times}$, on the rearwardly projecting parts of the shear-arms strike an adjustable stop, 11, on the furnace casing and close the shears on the issuing stream of molten metal. According to the invention, the mechanism is moved backwards and forwards along the slide, 5, by a pneumatic cylinder instead of by cams, as hitherto.

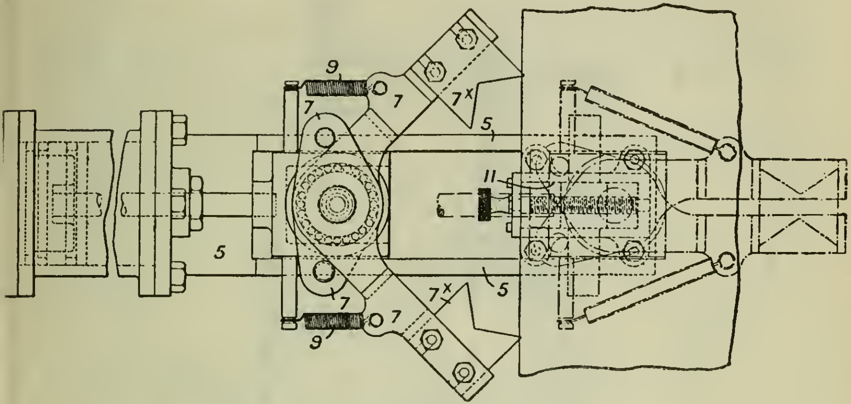

Fig. 208.

H. G. C.

410. Delivery of Hot Glass to Moulds. T. C. Moorshead, London (Brit. Pat., No. **176980**, January 26th, 1921).—Molten glass or other heated stream flowing from a furnace is uniformly and continuously heated to a temperature not less than that at which it leaves the furnace until it reaches the receiving mould. A full charge of metal in the mould is thus ensured without chilling the outer surface of the charge. As shown in the diagram, Fig. 209, the stream which leaves the furnace, 2, and nozzle, 7, flows through the muffle, 8, which is heated by a Bunsen burner, 9, until the mould, 4, is reached. During the substitution of one mould for another, the stream is cut off by the swinging knife, 5. H. G. C.

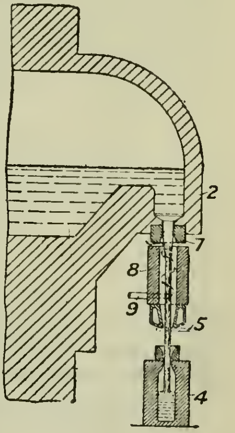

Fig. 209.

411. Glass Feeding Device. F. O'Neill, Toledo, Ohio, U.S.A. (Brit. Pat., No. **179977**, January 12th, 1921).—Relates to apparatus for delivering uniform charges of molten glass from a tank furnace. According to the invention, a plunger, d, is reciprocated in a cylindrical opening, c^2, which ends in a conical outlet, c^1, formed in a removable block, c, the plunger, d, being given a quick down-stroke and a slow up-stroke by a pneumatic cylinder, f, working through rack-and-pinion gear, n, n^3, n^6, n^7. The speed of movement of the plunger on the up- and down-strokes is controlled by valves comprising a ball valve, *g*, and an adjustable by-pass, *j*. The extent of movement is limited by adjustable stops, O^1, O^2.

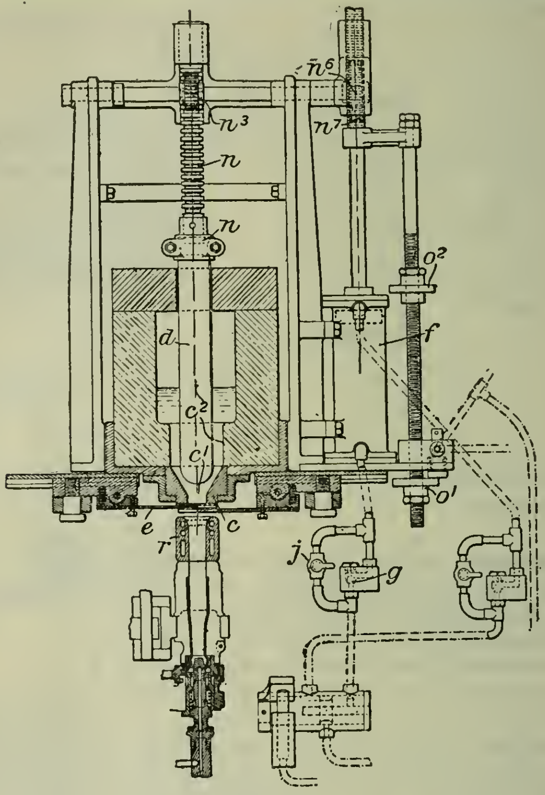

FIG. 210.

Shears, *e*, are operated by pneumatic gear, and the charge falls into a funnel, *r*, as described in Specification 166605. Specification 27227/05 is referred to. H. G. C.

412. A Cam-actuated Valve for Glass-working Machinery.

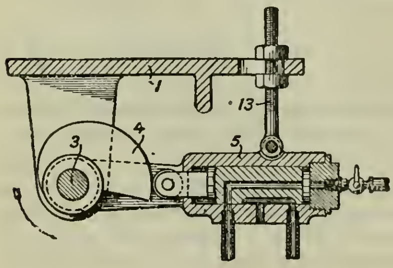

FIG. 211.

M. White, York, and A. E. Clegg, Leeds (Brit. Pat., No. **180895**, May 28th, 1921).—A cam-actuated valve for glass-working machinery and the like, particularly for apparatus for delivering charges of molten metal, has the valve body, 5, pivoted on the shaft, 3, of the cam, 4, and adjustably supported by a screwed rod, 13, on a fixed part, 1, of the

machine. Thus, the timing of the valve may be adjusted while the machine is in motion by adjusting the nuts on the rod, 13.
H. G. C.

413. Device for obtaining Charges of Molten Glass. Pilkington Bros., Ltd., A. C. Pilkington, and J. Gaskell, all in St. Helens, Lancashire (Brit. Pat., No. **177682**, March 3rd, 1921).—Relates to a gathering apparatus of the pipette type in which the metal is drawn into the gathering-vessel or pipette, 1, Fig. 212, by suction or by dipping the vessel into the metal and closing the upper outlet, 3. According to the invention, the lower opening, 2, of the pipette is closed by an obturator, 4, which has a cavity, 11, on its upper surface adapted to contain a small quantity of glass, so that when this obturator is moved to one side to permit discharge of the metal, the glass in the cavity, and any chilled strings, 13, are removed from the opening, 2. The obturator is pivoted by arms, 5, to the side of the pipette and in operation is moved in the same direction both to cover and uncover the opening, 2. The device is particularly intended for gathering and delivering metal for casting searchlight mirrors.
H. G. C.

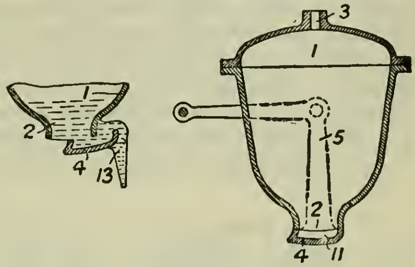

Fig. 212.

414. Manufacture of Incandescent Electric Lamps. H. D. Madden, Irvington, New Jersey, U.S.A., Assignor to Westinghouse Lamp Co., Pa., U.S.A. (U.S.A. Pat., No. **1349686**, August 17th, 1920. Filed July 11th, 1916, No. 108629).—According to this invention, machines for "sealing-in" electric lamp filament supports are provided with an automatic means for centring the mounts within the bulbs during the entire sealing-in operation, and also for extending or pulling out the seal towards the end of the operation. A pointed rod is inserted through the hole in the bottom of the bulb, and brought to bear in a depression in the centre of the end of the filament supporting the arbour. The rod is rigidly maintained in line with the axis of the bulb during the sealing-in operation, and after the seal is made the rod is forced downwards approximately one-eighth of an inch to draw out the joint. The seal is then annealed, the mount still being held central by the positioning rod, which is withdrawn when the seal has cooled sufficiently to be rigid. The hole in the bulb through which the positioning rod has been withdrawn is then used for the ordinary tabulation process.
S. E.

415. Machine for Making Electric Incandescent Lamps. British Thomson-Houston Co., Ltd., London, and General Electric Co., Schenectady, New York, U.S.A. (Brit. Pat., No. **180125**, March 18th, 1921).—In a machine for making stems for tip-less lamps of the kind described in Specification 147,293, means are provided for closing the clamps of the supporting-heads successively on to the several ports of the stems and for effecting the simultaneous opening of the clamps. The stem tube, 78′, the exhaust tube, 98, the caneglass, 59, and the leading-in wires are held, respectively, by clamps, 80, 91, 52, 65, the arms of which are pivoted on common rods, 53, 56. The leading-in wires are positioned in supports, 110, on the clamp, 80, and in guide-tubes, 102, pivoted at their lower ends in a member, 103, a yoke, 104, drawn down by springs, 106, tending to draw the upper ends of the tubes, 102, together. Springs, 60, 86, 95, tend to close the clamps. The clamps, 52, 65, can be opened either by a finger, 57, secured to a vertical shaft, 34, and acting upon a pin, 58, to actuate links, 51, 54, connected to the arms of the clamp, or by the operation of a bell-crank lever, 45, by a link, 43, pivoted to a sleeve, 36, surrounding the shaft, 34. These movements are effected by a handle, 37, secured directly to the sleeve, 36, and adapted to turn the shaft, 34, through contacting fingers, 39, 35. The clamps, 80, 91, can be opened only by turning the shaft, 34, to operate fingers and links similar to those serving to open the clamp, 52, but relatively positioned so as to open or to close the clamps in succession. The caneglass, 59, is positioned by a supporting-rod, 105, which is raised into position by an incline, 108, on the handle, 37. This handle is moved to the left to actuate the rod, 34, to open all the clamps; then the stem tube, the exhaust tube, and the leading-in wires are successively placed in position and the handle is moved step by step to the right to close the clamps successively and to separate the guide-tubes, 102, the handle is then moved farther to the right to reopen the clamp, 52, the caneglass is inserted, and the handle returned to close the clamp, 52. When a stem is completed and the handle, 37, is moved to release all the clamps, a

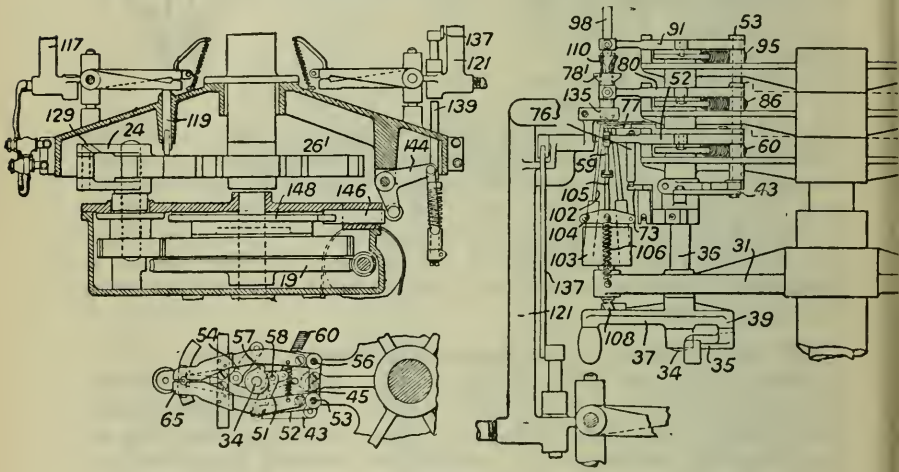

Fig. 213.

cam, 73, carried by the sleeve, 36, raises a rod, 76, and pivoted fingers, 77, which engage beneath the shoulder of the stem and lift it. Pairs of burners situated at several positions to which the stem parts are intermittently carried are mounted on bell-crank levers, 117, 121, etc., connected together so that a single tappet, 119, Fig. 213, operated by a cam, 129, on a geneva stop gear, 24, of the main driving-mechanism swings all the burners out of the path of the clamps during their travel from one position to the next. The lever, 121, also carries the pivoted members, 135, which pinch together the fused ends of the stem parts. These members are actuated by links, 137, a tappet, 139, connected through a spring to a lever, 144, a tappet, 146, and a cam, 148. The stem-supporting heads are mounted on a disc, 31, which is rotated intermittently from a worm wheel, 19, through geneva stop gearing, 24, 26′.

H. G. C.

416. Machine for the Manufacture of Vacuum-wall Containers. C. A. Rohland, Uniontown, Pa., U.S.A. Assignor to Vacuum Glass Machine Co., Uniontown, Pa., U.S.A. (U.S.A. Pat., No. **1436197**, November 21st, 1922. Filed April 2nd, 1921, No. 458117).—This machine is designed to make double-walled vessels at the furnace. The outer vessel, 0, Fig. 214, is pressed and blown into the shape of an ordinary wide mouth bottle, while the inner portions, 1, are formed into a rather long narrow shape with a wide head. As these two portions are blown in their separate machines, they are placed in rotating carriers mounted on two conveyors, which bring the upper portions of these blanks in between burners, thus keeping their flanged portions heated, but allowing the body portions to cool. The two portions are placed in holders mounted on a rotary machine which bring the narrow vessel inside the outer one and correctly place the two heated necks together. The head carrying the narrow portion makes an air-tight fit with the top of the cup holding the outer portion, and as it comes into position a valve is opened, withdrawing the air from the cup and the bottle-shaped outer vessel. At the same time, a piston presses the two heated portions together with such force as to form a continuous joint or union between the two sections, *V*. After further rotation of the machine the completed double-walled vessel is removed by hand for annealing.

S. E.

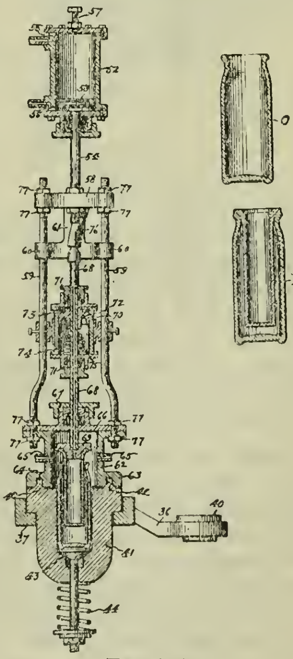

Fig. 214.

417. Automatic Test-tube Making Machine. P. BORNKESSEL, Berlin (Brit. Pat., No. **177884**, January 7th, 1921).—Relates to automatic apparatus for making two glass tubes, with one end closed, such as test-tubes, from a single open-ended tubular blank. According to the invention, the blanks, *d*, are fed singly from a hopper, *A*, of the shape shown, by an oscillating elevator, *e*. They are lifted by an oscillating cam-operated conveyor, 7, from the position, *f*, on to supporting rollers, *g*, where they are heated centrally by a burner, *h*. They are removed to an intermediate rest, *i*, and from thence to a device, *B*, of known kind, which divides the blank centrally into two tubes having sealed ends. These are passed to cooling stations, *l*, *m*, and then to a collecting device, *C*, which delivers them into boxes. The sharp edges may be melted by burners. H. G. C.

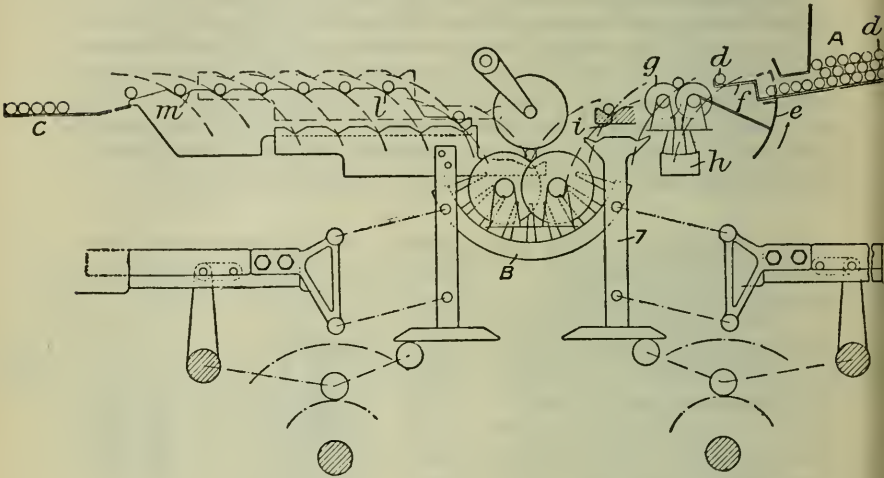

FIG. 215.

418. A Machine combining Cracking-off and Grinding. A. B. KNIGHT, Fairmont, W. Va., U.S.A. (Brit. Pat., No. **179304**, February 3rd, 1921).—Apparatus for cracking-off and grinding glassware are incorporated in one machine, and are actuated from the same power shaft. The grinding apparatus is similar to that described in Specification 169048, and comprises a number of grinders in housings, 6, Fig. 216, behind each other, which grinders are mounted on spindles, 5, belt-driven from a shaft, 48. Rods, 21, slide in sleeves, 22, and carry chuck-holders, 14, towards the grinders under the action of weights, 27, and are successively moved therefrom by bell-cranks, 35, engaging cams, 41, on a cam shaft, 42, which is worm-driven from a shaft, 45. The shaft, 48, drives a sleeve, 57, in which slides a splined shaft, 55, carrying a friction wheel, 59, engaging a friction disc, 60, on the shaft, 45. The speed of the cam shaft is varied on axially moving the wheel, 59, by means of a screw, 80. The disc, 60, is pressed against the wheel, 59, by a spring, and can be disengaged therefrom by operating a treadle, 73. Each chuck-holder, 14, has an eccentric opening, 15, in which fits a chuck, 7, having an eccentric ring, 10, lined with felt, etc., to receive the work, 11. By turning the chuck in its holder, the position of the work relatively to the grinder is varied. The cracking-off apparatus comprises a scoring-device, 106, revolving work-holders, 83, and burners, 123. The base of the glass to be scored is supported in a V-support, 105, and the outer edge by a member, 104, which together with the diamond, 106, is adjustable with respect to the V-support, 105. Each work-holder is formed of a plate, 84, having radial slots, 85, and a boss, 92, on which is screwed a plate, 87, having spiral slots. Pins, 89, engage both sets of slots, and are varied in position by rotating the plate, 87, relatively to the plate, 84, so as to grip the work. A nut, 93, secures the plates in position. The holder is mounted on a shaft, 94, driven through a shaft, 99, from the sleeve, 57. Supply pipes, 122, to the burners, 123, are slidable in members, 121, and locked therein by set-screws, 123^1. The members, 121, can be rotated relatively to integral sleeves, 112, 113, which are vertically adjustable on posts, 110, 111. Revolvable tables, 125, 126, serve as trays for the articles. H. G. C.

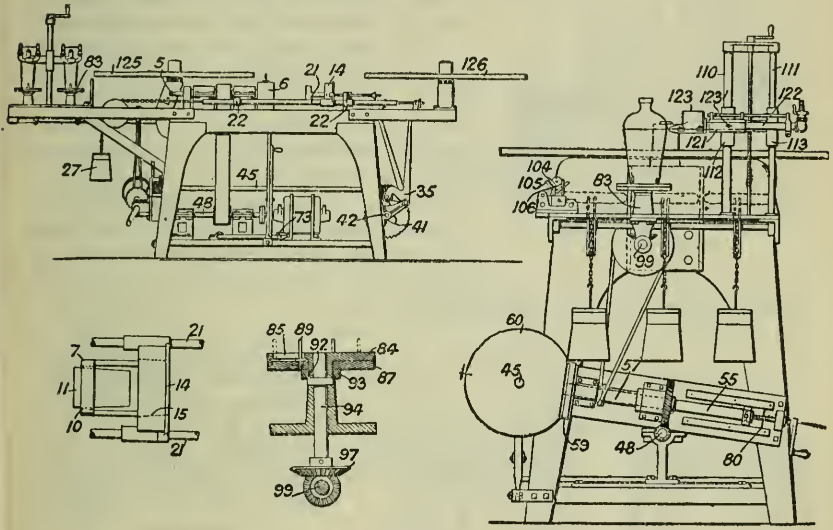

Fig. 216.

419. Glass Cylinder Drawing. H. F. Clark, Oakmont, Pa., U.S.A., Assignor to the Empire Machine Co., Pittsburg, Pa., U.S.A. (Brit. Pat., No. **181308**, September 6th, 1921).—Relates to the drawing of glass cylinders, particularly from a body of metal contained in the forehearth of a tank, and consists in cooling the glass more on one side of the cylinder than on the other in order to secure cylinders of uniform thickness. In the construction shown, the cylinder is surrounded by a hollow water-cooled ring, 2, the ends of which are in planes inclined to one another. The greatest depth of the ring is arranged nearest the tank, and the cooling effect is greatest on this side. The ring may be adjusted vertically by means of the supporting-ropes, 7, and may be shifted sideways, and it may be tilted by adjusting turn-buckles, 9. The ring may also be suspended in an inverted position so that its lower edge is parallel with the surface of the metal in the fore-hearth. In a modification, the ring is of oval form instead of being circular. In another modification, the ring consists of semicircular parts hinged together, so that the cooling effect may be varied by opening the sections more or less and turning them around the cylinder. H. G. C.

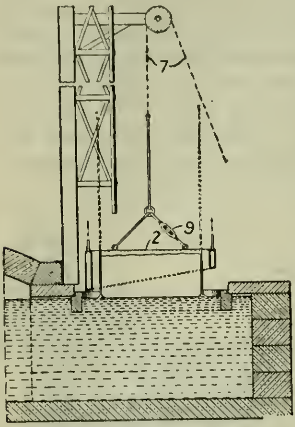

FIG. 217.

420. The Continuous Drawing of Glass Cylinders. C. P. BYRNES (U.S.A. Pat., No. **1425746**, August 15th, 1922. Filed January 28th, 1918, No. 214065).—The invention relates to a continuous process of drawing glass cylinders, and consists of means for gripping and drawing the cylinder and for cutting it off into sections during the drawing operation.

The body of metal, 3, Fig. 218, from which the cylinder is drawn is contained in a forehearth, 4, and its temperature at the drawing point is regulated by a clay ring, 12, and an adjustable water-cooled ring, 13. Air for distending the cylinder is supplied through a nozzle, 8, and

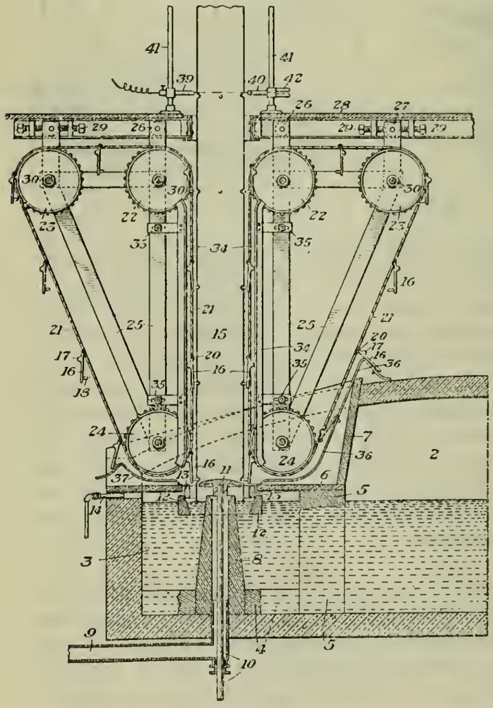

FIG. 218.

is deflected by a baffle, 11, so that it exercises pressure on the cylinder over the area where the glass is still plastic.

The drawing mechanism consists of endless chains, 21, located at four points around the cylinder and arranged to have vertical runs close against the cylinder. Hangers, 16, are pivoted at intervals along the chains and each hanger has a projection, 18. While the hangers are passing along the lower runs of the chains, they are held backwards by guides, 36, 37, until they approach the cylinder. As each hanger clears the chain, it is forced to swing forwards through its contact with the lower end of vertical guide bars, 34. The forward swing causes the projection, 18, on the hanger to make an indentation in the plastic wall of the cylinder, and as the hangers are kept in the forward position by the guide bars, 34, the projections, 18, thus lift the cylinder.

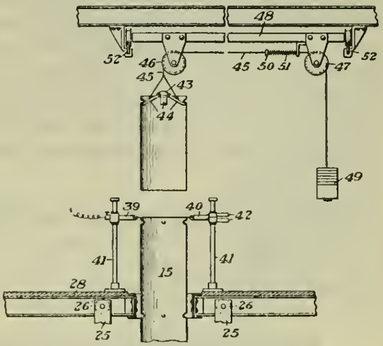

FIG. 219.

The cutting of the cylinder into sections is performed by an electrically heated wire carried by supports, 39, 40, which can slide upwards with the movement of the cylinder. Grippers, 44, Fig. 219, which are pulled upwards by a weight, 44, are inserted in the cylinder and grip it beneath the indentations. As soon as the wire cracks the cylinder, the top section is drawn upwards by the weight and the wire is moved downwards to make the next crack. G. D.

421. A Method of Drawing Sheet Glass Continuously. J. R. SCOHY (U.S.A. Pat., No. **1420868**, June 27th, 1922. Filed July 24th, 1920, No. 398798).—The invention relates to a process of drawing glass in a continuous sheet, and consists of means for maintaining the width of the sheet as it is drawn and of means for cutting the sheet into sections.

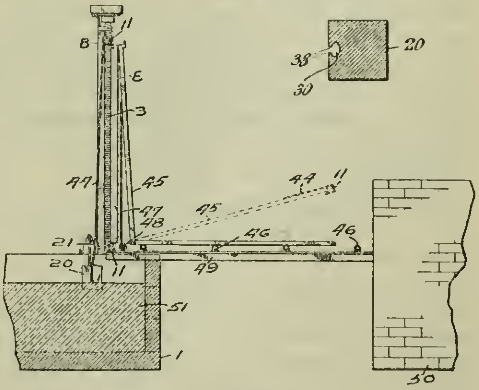

FIG. 220.

In order to maintain the width, the edges of the sheet, 44, Fig. 220, are drawn through channels, 30, in the faces of refractory blocks, 20, so that they are partly submerged in the glass. The edges of the sheet are formed from metal which fills the lower parts of the channels, 30, and the narrow slot, 38, prevents the thickened edge from drawing out of the channel.

The sheet is drawn upwards by a horizontal bar, 11, which is raised by vertical screws, 3, constantly rotated by a motor. When the bar nears the top of the screws, a new bar is engaged with the lower end of the screws. The top bar is then disengaged and placed on a frame, 45, which swings downwards into the horizontal position. The sheet is thus bent about the lower bar, 11, and the horizontal section can be sheared off. The lower bar then continues the drawing while the detached section of the sheet is fed into the lehr, 50. G. D.

422. Improvements in the Method of Drawing Sheet Glass. H. F. Clark and The Window Glass Machine Co. (U.S.A. Pat., No. **1424155**, August 1st, 1922. Filed August 5th, 1919, No. 315426).—Relates to the process of drawing glass in flat sheets, and consists of a method of avoiding or minimising the "pimpling" or marking of the surface of the sheet due to contact with the roll or rolls used in the drawing apparatus. In Fig. 221, the invention is shown applied to apparatus of the type in which the sheet, 8, is drawn vertically upwards and then passes around a bending-roller, 3, into the horizontal position. According to the invention, the under surface of the sheet, which has been marved by the bending-roll, 3, is fire-polished either by heated air or by gas or oil fumes, which are directed against the surface immediately after it has passed out of contact with the bending-roll. For this purpose, a distributor, 5, which consists of a pipe with continuous or interrupted jet openings, 6, is arranged to direct the air against the surface of the glass. A cooling jet, 9, may be arranged immediately behind the distributor in order to harden the fire-polished surface of the sheet before it touches the drawing rolls. G. D.

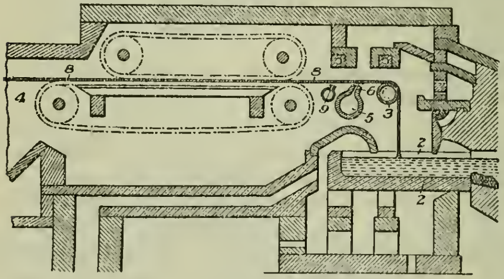

Fig. 221.

423. A Glass Cutter. J. R. Scohy, Okmulgee, Oklahoma, U.S.A. (U.S.A. Pat., No. **1435985**, November 21st, 1922. Filed December 11th, 1920, No. 429842).—This glass cutter is designed for severing glass cylinders, and consists of a high resistance wire attached to the ends of two fork-like arms which spring from a handle of insulating material such as fibre. The leading-in wires carrying the current to the high resistance wire pass through the handle and then separate, one passing through each arm. A pring-controlled switch is included in the handle. S. E.

424. The Continuous Drawing and Severing of Sheet Glass.

H. S. Campbell (U.S.A. Pat., No. **1367858**, February 8th, 1921. Filed December 23rd, 1919, No. 346852).—Relates to apparatus for drawing glass in a flat sheet and consists in providing means for cutting the sheet into sections.

The drawing apparatus consists of endless chains, 10, 11, Fig. 222, provided with links, 12, having serrated faces, 13, which grip the edges of the sheet between them and thus apply the drawing power. At intervals, the chains have cross-bars, 14, 18, which extend across the sheet, and these bars have serrated faces, 15, 18*a*, as shown. The faces of the bars are also fitted with strips, 16, 19, of German silver, or other suitable material, which is heated electrically. Thus the sheet, while gripped by the bars, is heated along a transverse line, where it is weakened by the grippers and a crack results. G. D.

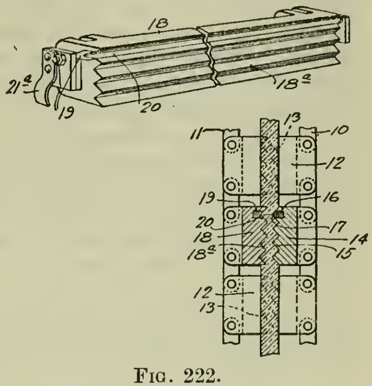

Fig. 222.

425. A Method for Drawing Wire Glass.

C. A. Rowley and The Libbey-Owens Sheet Glass Co. (U.S.A. Pat., No. **1425218**, August 8th, 1922. Filed February 17th, 1921, No. 445602).—A method of making wire glass consists in drawing a continuous sheet from a mass of the molten metal and then dipping it, along with the wire mesh, again into the metal so as to unite the wire with the sheet and to pick up a new sheet of glass to cover the wire mesh.

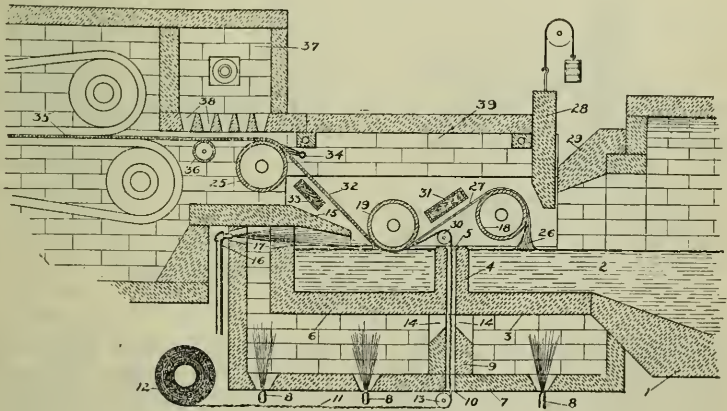

Fig. 223.

The apparatus for carrying out the process is shown in sectional elevation in Fig. 223. A tank, 1, is provided with a forehearth, 6, across which a wall, 4, extends and is built over a heating-chamber, 7. A slot, 5, through the wall, 4, allows the introduction of the wire netting, 10, from a roll, 12, a space, 14, below the slot permitting the netting to be heated by the flames in the heating-chamber. Two rolls, 18, 19, are arranged transversely above the forehearth, and they are arranged to be cooled by a water supply circulated in their interiors.

A sheet, 27, is drawn over the roll, 18, and passes beneath the surface of another roll, 19. The wire which is drawn upwards through the slot, 5, passes over a roll, 30, and makes contact with the glass sheet just before it passes beneath the roll, 19. This roller is adjustable so that its surface just dips beneath the surface of the metal. The sheet, 27, which is still hot, unites with the wire and picks up a further supply of metal, thus forming a compound sheet, 32, which passes on to the lehr. Water-coolers, 31, 33, are placed near the sheet to harden the surface before it makes contact with a roller and thus prevent damaging the surface.

G. D.

426. Grinding, Polishing, and Burnishing Glass, etc. J. Carril, Newark, N.J., U.S.A. (Brit. Pat., No. **177049**, March 12th, 1921).—In a machine for grinding, polishing, and burnishing plates of glass, marble, etc., the plate is carried by a table, which is reciprocated beneath two grinding or polishing discs having planetary motion, and the pressure of the discs on the work is varied by raising or lowering the head carrying the discs. The glass, etc., is carried on a table, 4, which is reciprocated on tracks, 6, by rack-and-pinion gearing, 7, 8, driven, through a shaft, 9, worm-gearing, 11, and variable-speed friction gearing, 13, 14, by open and crossed belts engaging pulleys, 20. The belts are shifted by a fork, 15, operated, through levers, 17, 19, and an arm, 22, by dogs, 23, 24, mounted on the table. The grinding or polishing element comprises two discs, 1, carried by arbours, 26, mounted with slight axial freedom in a head, 27, which is carried by a vertical

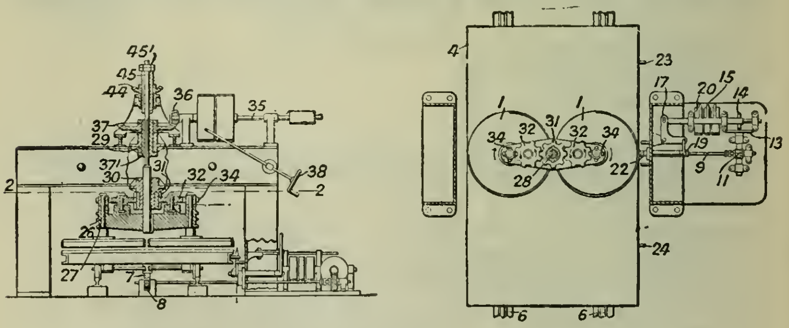

Fig. 224.

shaft, 28, mounted in bearings, 29, 30, carried by beams, 2. The bearing, 30, carries a stationary gear, 31, which, on rotation of the head, drives the discs through idle gears, 32, and pinions, 34. The shaft, 28, is slidably keyed to a bushing, 37^1, carrying a bevel-gear, 37, and is driven by a bevel-gear, 36, carried by a shaft, 35, driven from the pulley, 20. The shaft and the head are supported by a collar, 45^1, on the shaft, which rests on a threaded sleeve, 45. The sleeve may be raised or lowered by rotation of an internally-threaded bevel-wheel, 44, which engages the sleeve and is rotated, through worm-gearing, by a hand-wheel, 38. In operation, a light cut is first taken from the work by adjusting the head so that, owing to the axial freedom of the arbours, 26, the pressure of the discs on the work is due to the weight of the discs only. A heavy cut is then taken by lowering the head so that the pressure of the discs is due to the full weight of the parts. H. G. C.

427. Grinding Lens Edges. R. Schumann, Düsseldorf, Germany (Brit. Pat., No. **180731**, February 21st, 1921).—In a machine for grinding the edges of spectacle glasses, the glasses and a number of templets, corresponding in form with the most commonly-used shapes of glass, are mounted to rotate in a support which is rocked about an axis parallel to the axis of the grinding-wheel; a roller abutment co-operates with the required templet and the support is reciprocated by means of a cylinder cam arranged to give an adjustable stroke to the support. A grinding-wheel, 4, is journalled in a bed, 1, and on ways, 5, on the bed is adjustably mounted a slide, 6, in which is rotatably mounted an axially slidable shaft, 10. This shaft is driven, through gearing, 47, 47^a, and a shaft, 59, having therein a clutch, 54, from the shaft of the grinding-wheel. On the shaft, 10, is mounted a sleeve, 11, having arms, 12, provided with bearings, 16, 24, for shafts, 17, 27, respectively. These shafts carry at their opposed ends rubber-faced discs, 18, 25, for holding the glasses being ground, and on the shaft, 17, are mounted templet discs, 32, the various forms of which correspond with the most commonly-used shapes of spectacle glass. The shafts, 17, 27, are driven at the same speed, through gearing, from the shaft, 10, and, in order to move the shafts axially to grip or release the glasses, the outer ends of the shafts have arms, 73, 74, resiliently mounted thereon. The outer ends of these arms carry axially aligned parts, 75, 76, the opposed ends of which are screwed with right-handed and left-handed threads, respectively, to receive a correspondingly threaded union, 80. Rotation of the union moves the discs, 18, 25, towards or from each other. The sleeve, 11, carries a weight, 23^a, which presses the glasses up to the grinding-wheel. On the slide, 6, is mounted a bell-crank lever, 35, carrying at its forked upper end a shaft, 34, on which is slidably and rotatably mounted a flanged abutment roller, 33, adapted to co-operate with any of the templets, 32, the lever being adjustably fixed in position by a stud, 41, and a nut, 40. To hold the glasses away from the grinding-wheel, the support is rocked so that a pin, 43, thereon engages with a notch in a pivoted lever, 45^a. This movement brings a cam, 62, on the sleeve, 11, into engagement with a lever, 57, which disengages the clutch, 54, and stops the rotation of the glasses. On the shaft, 10, is secured

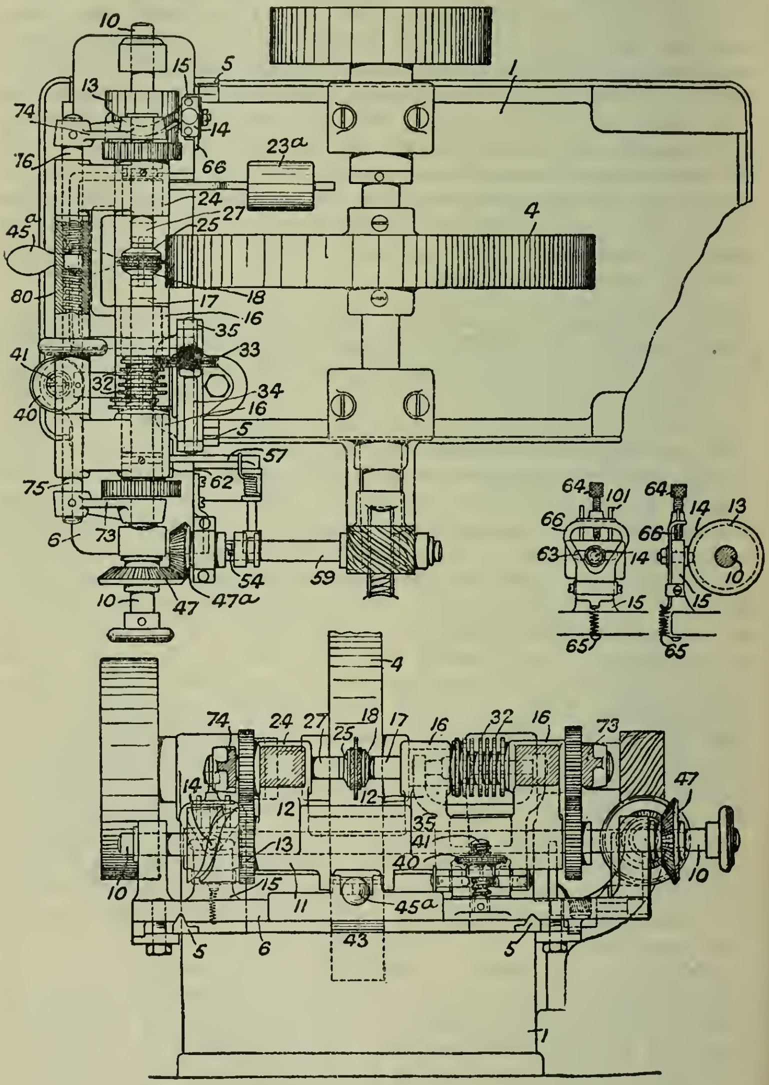

Fig. 225.

a cylinder cam, 13, engaging with a stud, 14, which is slidably mounted in a horizontal slot, 63, in a plate, 15, secured to the bed, 1. On the plate is mounted, by means of guide-pins, 101, a yoke, 66, which is held down by a spring, 65, Fig. 225, the position of the yoke being set by a screw, 64. The yoke is wider at the top than at the bottom, the effective length of the slot, 63, thus depending upon the position of the yoke. On the rotation of the cam, 13, with the shaft, 10, the stud, 14, moves along the slot until it is arrested by the yoke; continued rotation of the cam then causes the shaft, 10, and with it the glass-support, to slide axially. The reverse movement of the support takes place when the stud has reached the opposite side of the yoke. By adjustment of the yoke, the stroke of the reciprocation of the support may be adjusted according to the number of glasses being ground. In a modified construction, the stud is mounted at one end of a lever pivoted to the bed and is arrested by engagement with the sides of a V-shaped notch in an adjustable plate. H. G. C.

428. Bevelling Lenses, etc. Standard Optical Co. and E. M. Long, both in Geneva, New York, U.S.A. (Brit. Pat., No. **182538**, March 31st, 1921).—The lens or like article is rotated diagonally across and against opposed bevelled grinding-faces of a rotary grinding-wheel, and is so mounted as to be movable axially and transversely of the axis, whereby toric, cylindrical, and irregularly-shaped lenses may be ground. The grinding-wheel comprises two discs, 1, having opposing bevelled faces, 5, and separated by a thin disc, 6, of softer material, for example, felt. The discs are held on a shaft, 2, by a sleeve, 7, and a collar, 7^1, Fig. 226, the sleeve having passages, 10^1, for water, which is carried by centrifugal force outwards and through the pores of the wheel to the bevelled faces; the water is caught in a trough, 11. The lens, *a*, is supported in a vertical plane diagonally to the grinding-wheel by clamping-heads, 13. One head is carried by a spring-pressed spindle, 14^1, mounted in a bearing, 15^1, at the end of a carriage, 16, comprising two arms, 16^1, connected by a member, 37, and the other head is carried by a shaft, 14, and is connected to a sleeve, 22, mounted in a bearing, 15, coaxial with the bearing, 15^1. The spindle, 14^1, may be moved axially, for insertion or removal of a lens, by a lever, 33, which engages an annular recess in a collar on the spindle. The sleeve, 22, is provided with a gear-wheel, 24, and the outer end of the spindle, 14, carries a lens-pattern, 25. In order that the lens may rise and fall and move axially to keep the bevels in engagement with the grinding-wheel, the carriage, 16, is pivoted by horizontal pivots, 17, to a frame, 18, carried by fixed and adjustable vertical pivots, 19, on a support, 20. The support is vertically adjustable on guides, 40, 40^1, in a bracket, 21, on the main frame, 4, whereby different sizes of lenses may be ground and wear of the grinding-wheel compensated for. The lens-holder is driven through worm and spur gearing from a shaft, 45. The spur-gearing comprises a wheel, 57^1, connected to the worm-wheel, 57, and journalled in the bracket, 21, and driving a train of three wheels, 60, the first two of which are carried by spindles, 62, in the frame, 18, and the third by a spindle, 59, in the carriage, 16. The third wheel drives a wheel, 63^1, carried by a spindle, 63, which also carries a wheel driving the wheel, 24. The pattern, 25, contacts with a rest, 26, and, in order to feed the lens gradually down on to the grinding-wheel, the rest is mounted on the end of a lever, 64, pivoted at, 65, to the frame, 18, the other end, 66, of the lever engaging a cam, 67. The cam is connected to a ratchet-wheel, 69, and both are rotatably carried by a stud, 68, on the frame, 18, the ratchet-wheel being

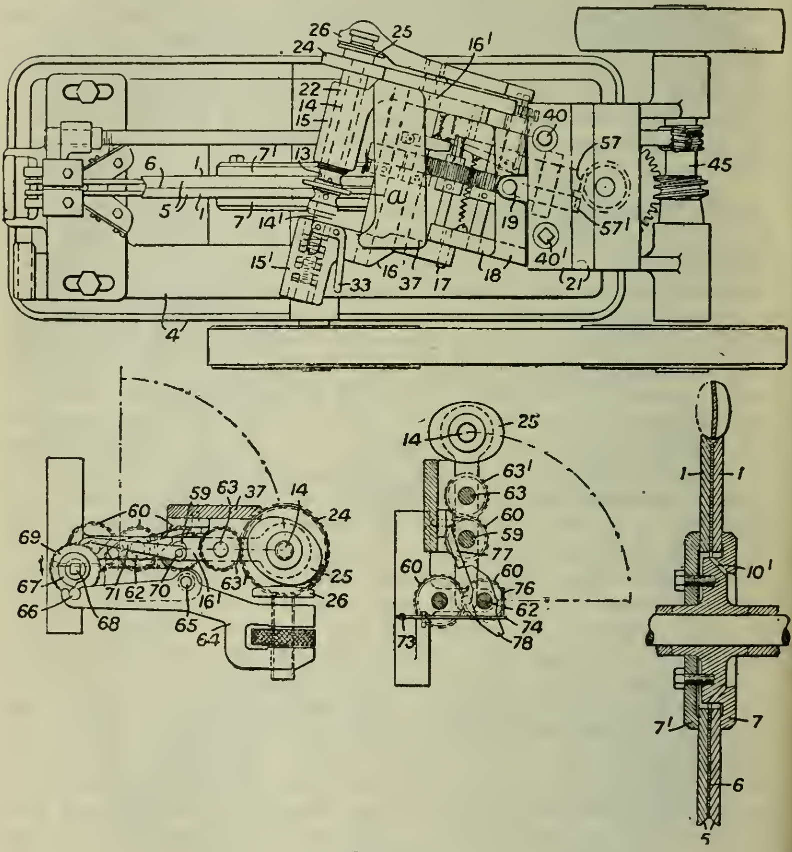

FIG. 226.

fed one tooth at each revolution of the shaft, 59, by a pawl, 71, carried by an eccentric pin, 70, on the shaft. The highest part of the cam initially contacts with the lever, and rotation of the cam gradually lowers the rest until the lowest part of the cam contacts with the lever; grinding is then completed, and the carriage is swung upwards to the position shown in the dotted lines in Fig. 226. This action is brought about by a member, 78, carried by the shaft, 62, which engages a lever, 77, pivoted on the bar, 37, and moved into the path of the member, 78, by a spring-pulled lever, 74. The lever, 74, moves to operate the lever, 77, when a bolt, 73, carried by the lever moves into a recess in the ratchet-wheel, this action taking place when the lowest part of the cam contacts with the lever, 64. The upward movement of the carriage resets the cam, 67, to its starting position and also releases the lever, 77, from the pin, 76. A new lens may then be substituted for the finished lens and the operations repeated.

H. G. C.

429. Grinding Bifocal Lenses. M. BENTZON, Neurilly-sur-Seine, Paris (Brit. Pat., No. **172367**, August 7th, 1920).—A machine for grinding bifocal lenses comprises a rotating lens-holder, *e*, and a series of grinding-wheels, *m*, mounted on holders, *n*, slidably carried by radial arms, *o*, which are angularly adjustable in vertical planes. The lens-holder is carried by a spindle, *f*, journalled in a vertically adjustable bracket, *h*, which is mounted on a pillar, *d* ; the spindle is rotated by a pulley, *k*. The arms, *o*, are pivoted at *p* to pillars, *r*, mounted on a head, *b*, and the angular setting of the grinding-wheels is determined by graduations, o^1, and verniers,

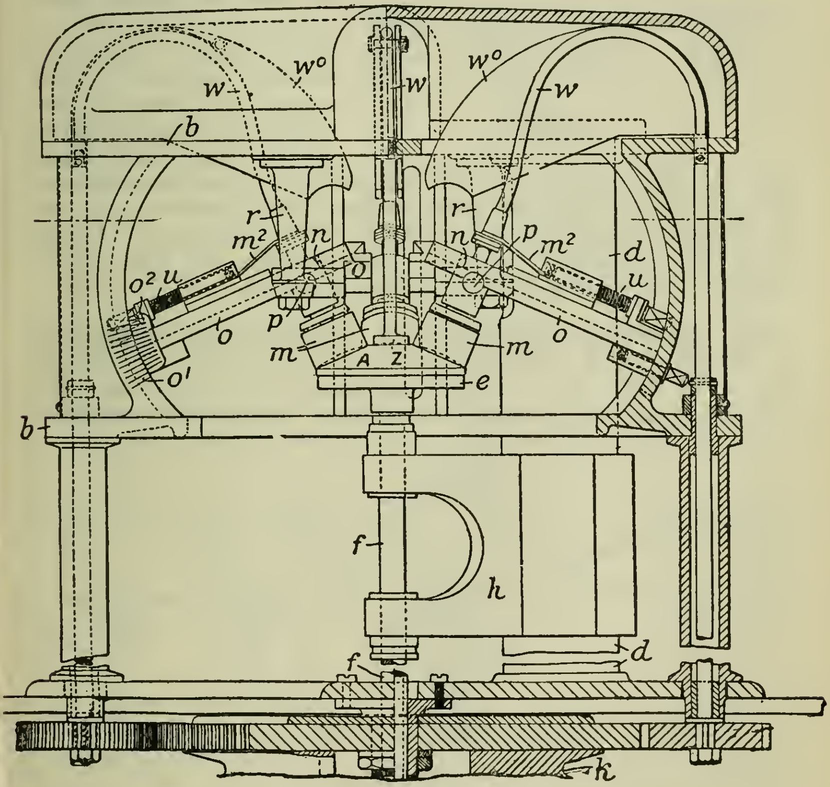

FIG. 227.

o^2, or by templets or gauges; the grinding-wheels may be set to grind convex, concave, or flat surfaces. The grinding-wheels are pressed axially by springs, m^2, and are driven by flexible shafts, *w*, guided between plates, w^0. The grinding-wheels are adjustable radially to the lens by means of screws, *u*, which move the holders, *n*, on the arms, *o*. A central stop, *z*, is provided on the head, *b*, for determining the grinding position of the lens, *A*. Specification 18109/10 is referred to. H. G. C.

430. Drawing Glass Cylinders. A. P. WHITTEMORE, Charleston, W. Va. (U.S.A. Pat., No. **1415133**, May 9th, 1920. Filed December 10th, 1920, No. 429677).—The invention relates to a means for securing uniform thickness in cylinders produced by drawing, and consists in using detachable shields, 5, which may be attached where desired to the inner side of the usual water-cooled ring, 1, which surrounds the cylinder near the drawing-point. The shields, 5, may be of metal covered with asbestos, and may be attached to the shield by hanging them on studs, 6. In use, the shields are attached to the ring opposite any part of the cylinder that is observed to require thinning. G. D.

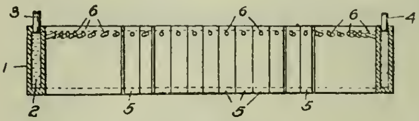

FIG. 228.

431. Automatic Remelting or Fire-polishing Apparatus. A. MEYER and H. BATTISTELLI, Paris (Brit. Pat., No. **172307**, November 30th, 1921. Convention date, November 30th, 1920. Not yet accepted).—Relates to automatic apparatus for remelting or fire-polishing the ends of glass tubes, etc. According to the invention, the tubes pass down a guide, *B*, are carried by hooks, *b*, on a wheel, *A*, past gas burners, *C*, *C′*, and delivered on to a discharge guide, *X*. The tubes are rotated by rollers, *K*, while they are under the action of the burners. In a modification, the tubes are rotated on their axes by a single large wheel instead of by the rollers, *K*. H. G. C.

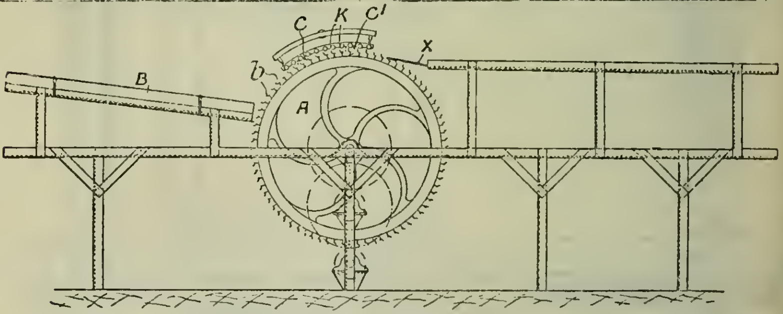

FIG. 229.

XI.—General.

432. Modern Glass Factory Equipment. W. S. MAYERS (*The Glass Industry*, 1922, **3**, 197 and 221).—The author suggested that large factory owners should pool their interests and divide the expenses in conducting research work in furnace design. In regard to air cooling it was pointed out that the running of a series of small fans in parallel was wasteful. The following was given as the formula whereby one could determine the size of motor required to drive any fan: H.P. = C.F.M. × W.G. × 5·2/33,000 × % fan efficiency where C.F.M. = cubic feet per minute; W.G. = total head in inches of water.

Air pressures required were usually under 60 lb., and high speed single stage compressors with short belt motor drives were general, due to their low first cost and small space required. With a plant of eight machines each requiring 250 c.ft. of air per minute a desirable installation would be three 250, two 500, and one 750 C.F.M. compressors, so that any demand might be met. Trustworthy automatic unloading arrangements were advisable, but it was better to run only one compressor in this way, keeping the others under steady load, and avoiding any possibility of simultaneous "peak-loads." Air taken into the compressor should be dirt free and not contaminated with batch, producer dust, or cullet powder. Blowers were really air compressors handling large volumes at low pressures, the centrifugal air compressor now replacing the positive rotary type in spite of bigger cost and its limitation in single stages to about 4 lb. pressure when directly connected to a motor with a speed of 3,500 r.p.m.

Bins should allow of two weeks' supply without replenishing, when supplying the full demand, the reserve being a fair insurance against delays in delivery. Present designs seemed to favour the electrically-operated weighing and mixing car travelling near the ground level in a passage under the bins, and discharging its contents into a hopper for later transference to the furnace. Bins were usually cylindrical with a conical top; but steel "sweated" in cold weather, and concrete must be made water-proof. Bases could be of steel plate or of concrete slabs. Plans of bins should be based on volumes rather than on weights, so that the relative contents for sand, 58 per cent. soda ash, and lime, should be 4 : 2 : 1 respectively. Rather than vary the size of the bins, it was better to vary the number, and have one divided if necessary. Pneumatic conveyers were a distinct advantage for the transference of soda ash and lime, especially in hot weather, when the substances caused irritation to the nostrils. W. S.

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